HOW IT WORKS

WIN £1,000 PRIZE BUNDLE

HOW DO WE KNOW DINOSAURS HAD FEATHERS?

HOW IT WORKS

THE MAGAZINE THAT FEEDS MINDS

100 YEARS OF THE RAF

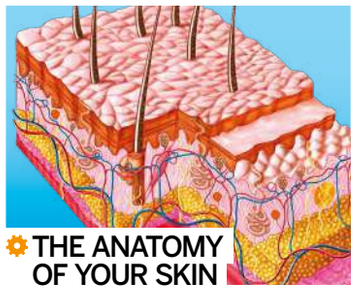
CAN YOU TRUST YOUR BRAIN?

SURVIVING EARTH'S EXTREMES

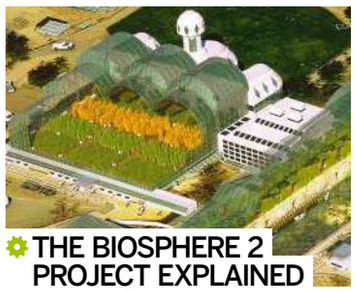
HOW LIFE THRIVES IN THE WORLD'S MOST INHOSPITABLE ENVIRONMENTS

DISCOVER

DISNEY'S NEW STUNT ROBOTS



THE ANATOMY OF YOUR SKIN



THE BIOSPHERE 2 PROJECT EXPLAINED

REVEALING MARS' MYSTERIES WITH INSIGHT

HOW REMEMBRANCE POPPIES ARE MADE

FUTURE

ISSUE 118

DISCOVER™
LANDS UNKNOWN

Embark on a Unique Journey

Explore the endless wilderness with *Discover: Lands Unknown*, a new Unique Game from Fantasy Flight Games! When you find yourself stranded in an unfamiliar environment, you and your friends must explore to survive! Every copy of *Discover: Lands Unknown* is completely unique, distinct from every other copy in the world! Do you have what it takes to survive?

DSC01 £57.99

UNIQUE GAME™

EVERY GAME UNIQUE!

FANTASYFLIGHTGAMES.COM

ISSUE 118

WELCOME

The magazine that feeds minds!

We humans are rather limited by the range of conditions we can naturally survive in. Too hot and we fry, too cold and we freeze, not enough oxygen and we suffocate. We may have engineered technologies to help us survive where we technically shouldn't be able to, but some organisms already manage to thrive in the most extreme locations. Few species epitomise the notion that "life finds a way" better than extremophiles, the lifeforms that call Earth's most inhospitable places home.

Also this month, we celebrate 100 years of the RAF, see how technology is transforming the fashion industry and look back on how 'talkies' and Technicolor changed Hollywood forever.

Enjoy the issue!

Jackie **Jackie Snowden**
Editor

"The Royal Air Force remains on the cusp of the latest aviation technology..."
Evolution of the RAF, page 64

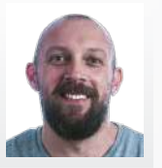
Meet the team...

Charlie G
Production Editor
I hadn't realised to what extent many dinosaurs were covered in feathers. *Jurassic Park* could be set for a clucking good reboot!

Baljeet
Research Editor
Discover how NASA's InSight spacecraft will work to improve our understanding of Mars on page 54.

Charlie E
Staff Writer
Can you trust your brain? Are your thoughts really your own? Check out how cognitive bias takes over your mind on page 38.

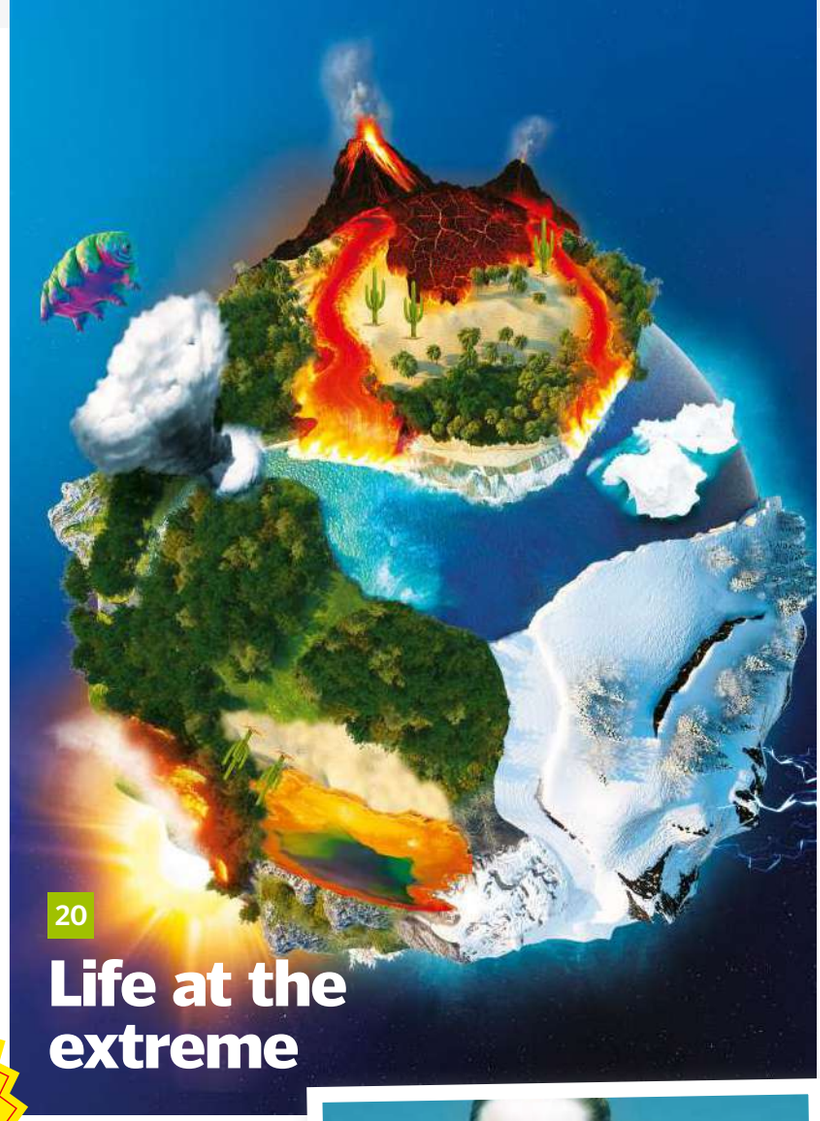
Scott
Staff Writer
Could printable dresses, AI active wear and lab-grown fabrics be the future of fashion? Find out more over on page 44.



Duncan
Senior Art Editor
As a massive movie fan I was interested to read about the Golden Age of Hollywood on page 76. *Jaws* would have been odd in silence!

FOLLOW US... How It Works magazine @HowItWorksmag

CONTENTS



20
Life at the extreme

76
The Golden Age of Hollywood

44
Hi-tech fashion

MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.

Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

Lee Cavendish
Avid stargazer Lee writes for our sister magazine, **All About Space**, and has a degree in observational astronomy.

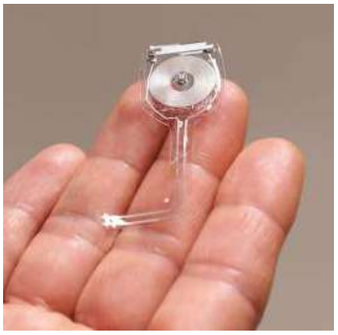
Stephen Ashby
Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.

Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.

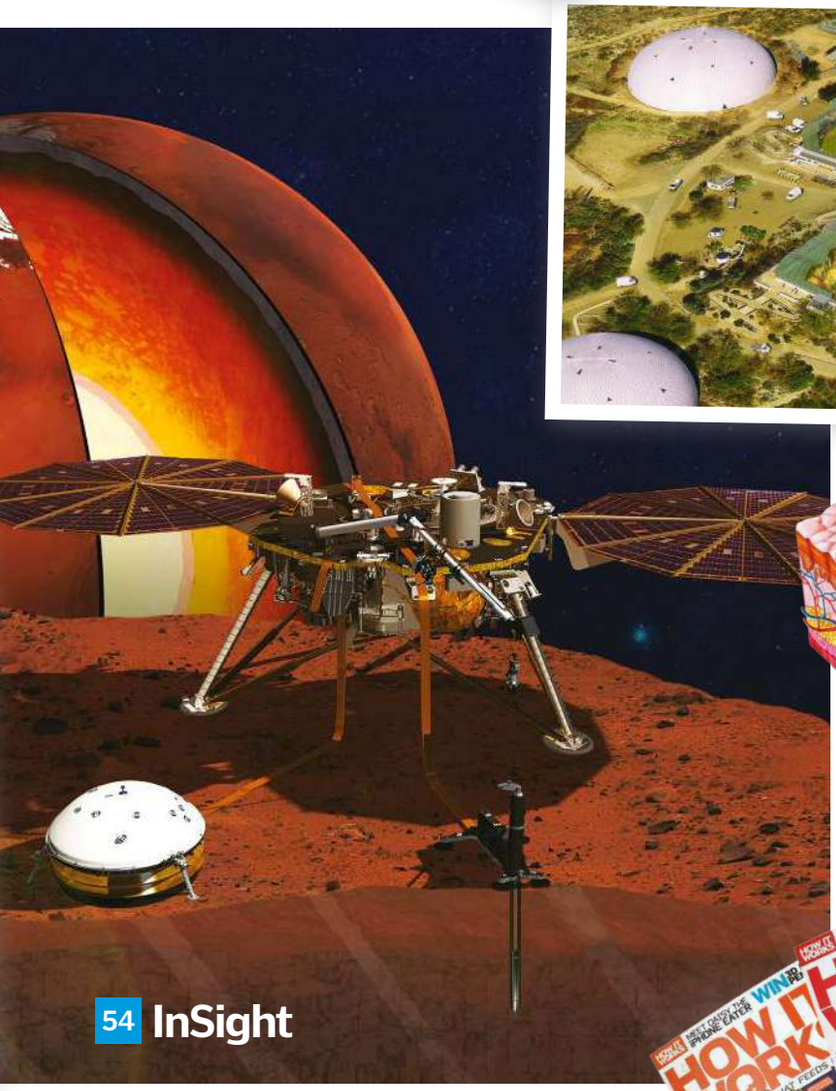
REGULARS

64
The evolution of the RAF

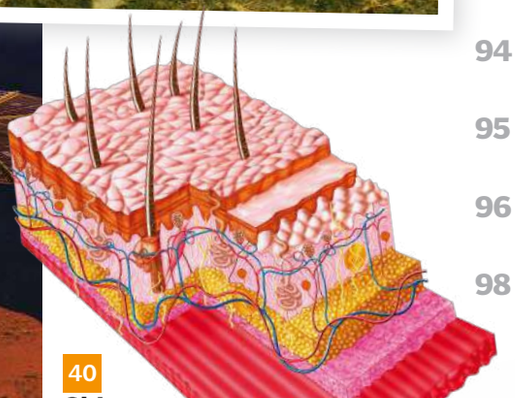
32
Small science



Biosphere 2 30



54 InSight

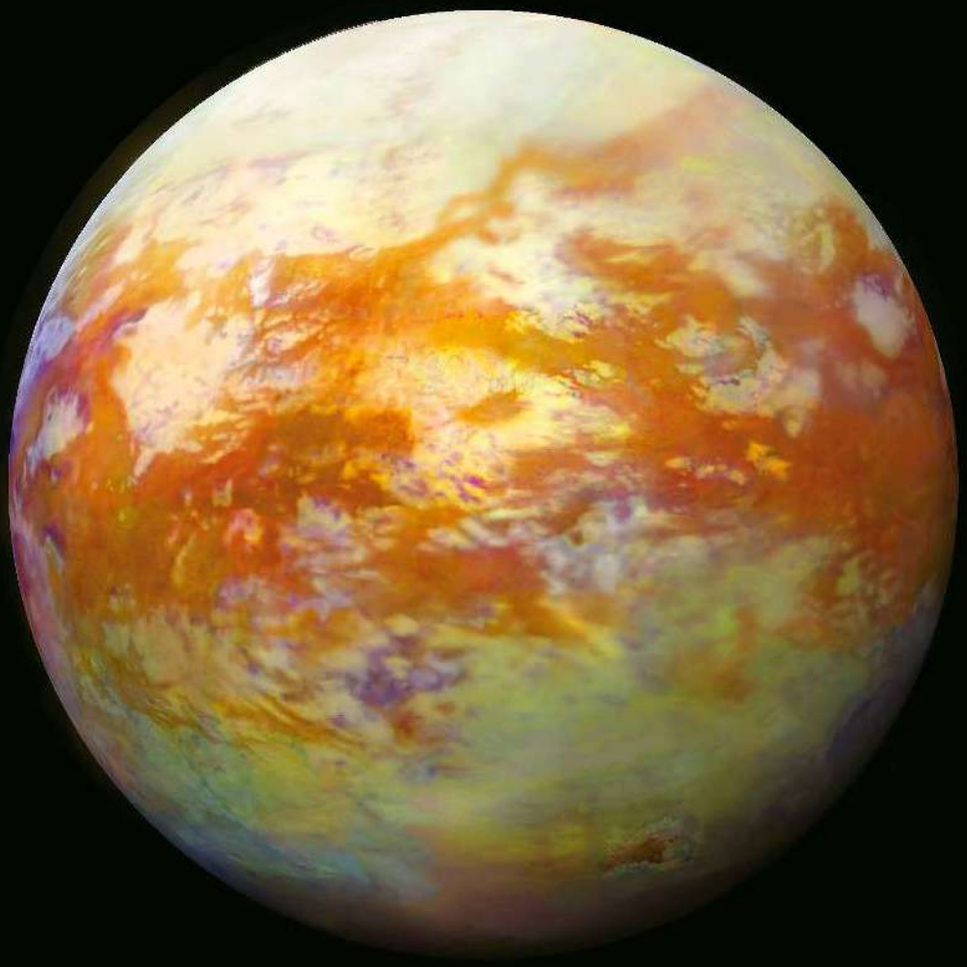


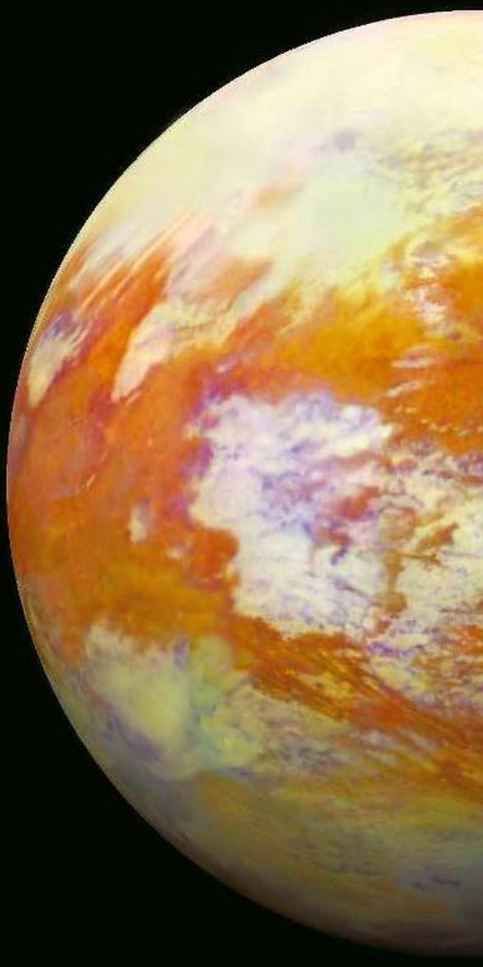
40
Skin anatomy

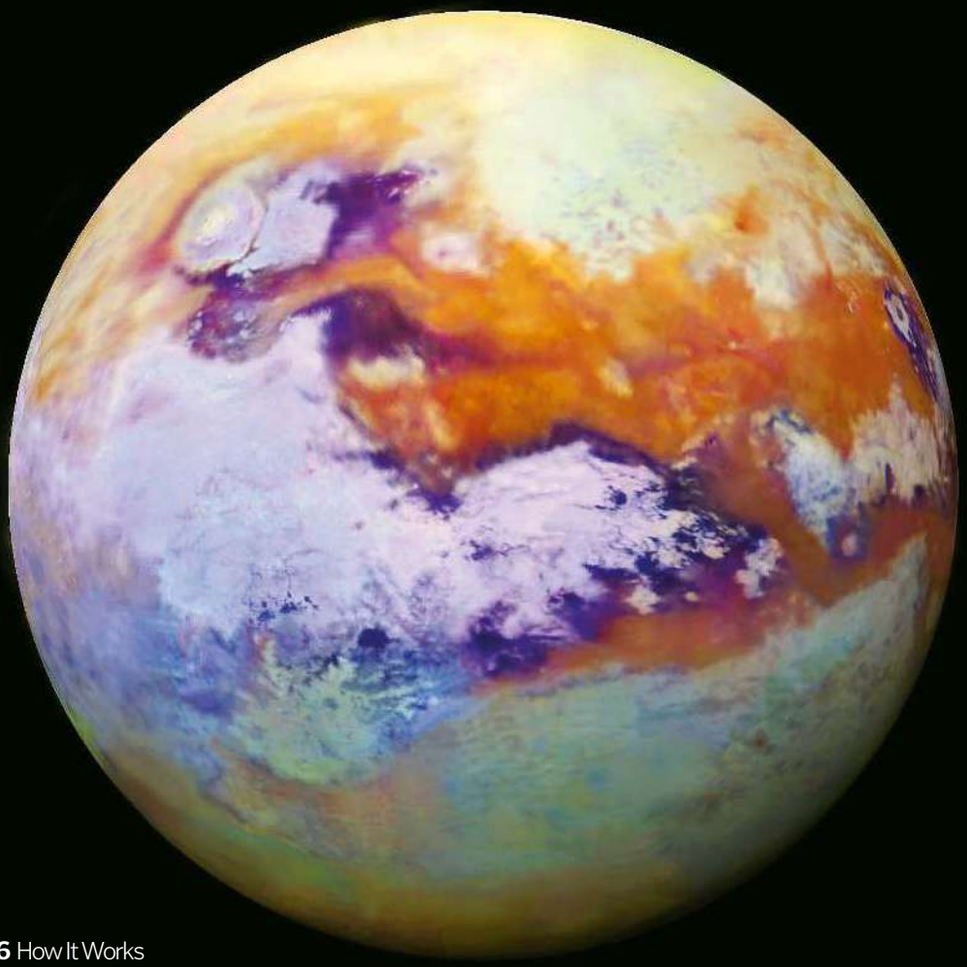
Tim Williamson
History Of War
Editor Tim has a passion for all things military but studies and writes about a range of historical eras.

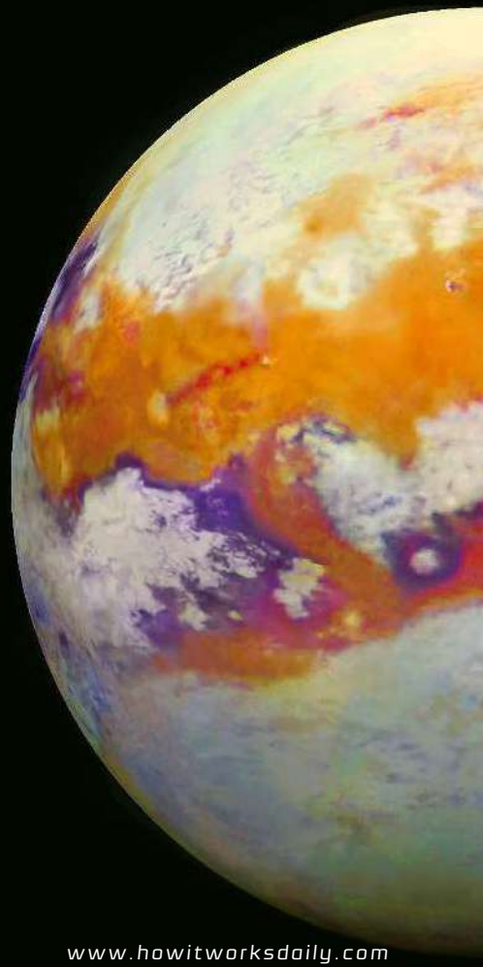
Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.

Victoria Williams
Evolutionary biologist and **World of Animals** writer Vicky is fascinated by the natural world and happiest when she's outdoors.



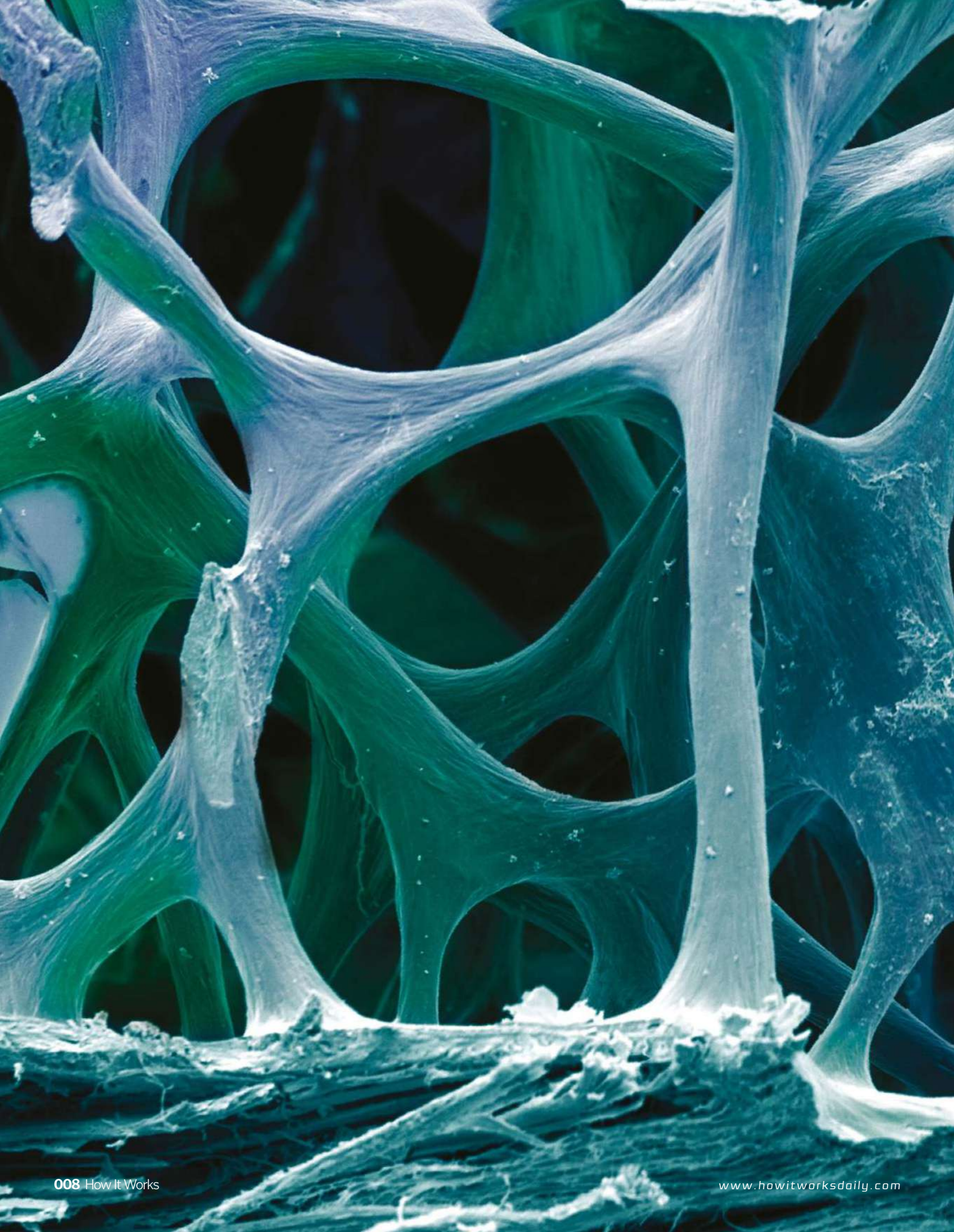


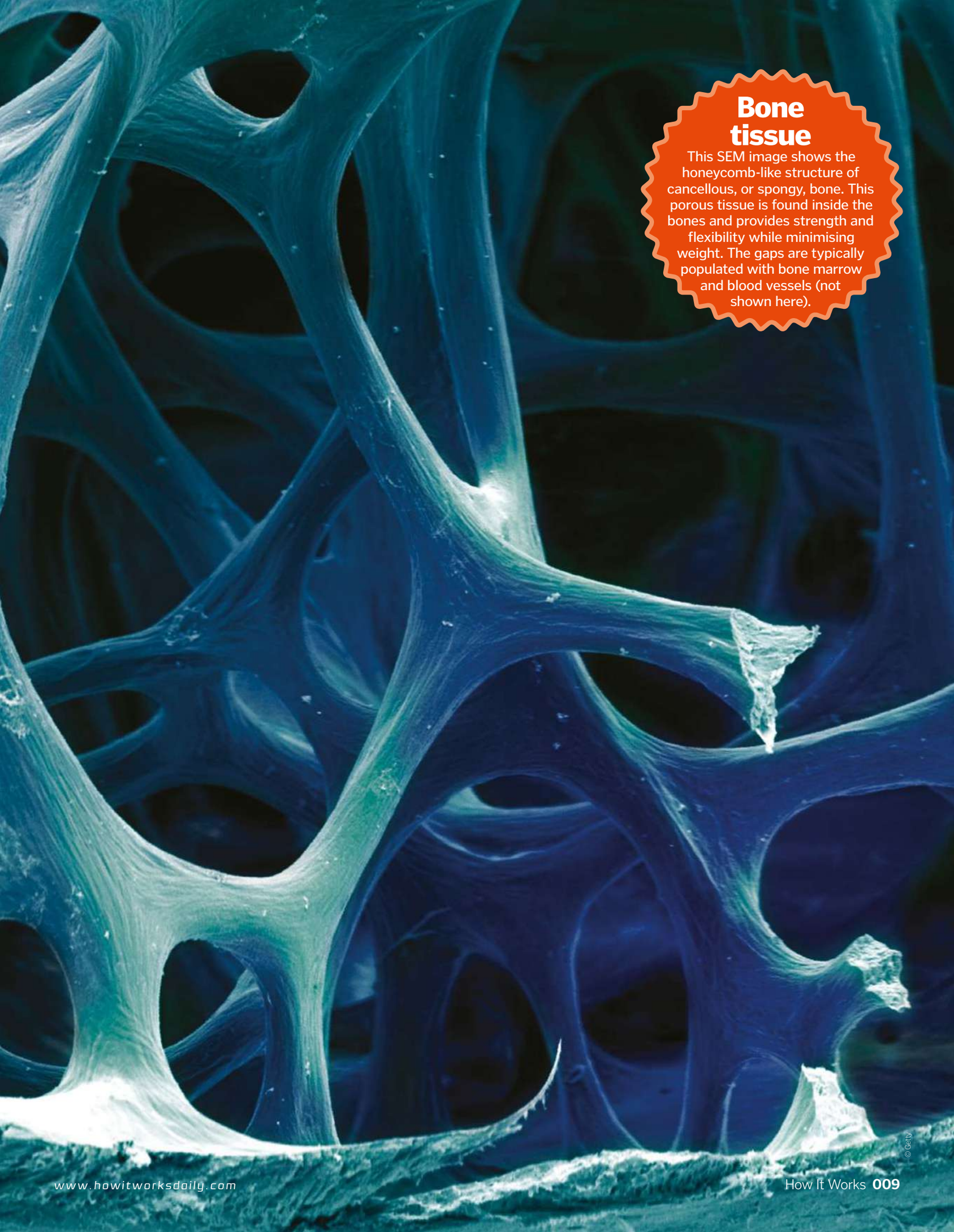




Titanic views

These infrared images of Saturn's icy moon Titan were created using 13 years' worth of data collected by Cassini's Visual and Infrared Mapping Spectrometer. Areas highlighted in purple-blue may have a different composition to the other bright regions, possibly indicating the presence of water ice.





Bone tissue

This SEM image shows the honeycomb-like structure of cancellous, or spongy, bone. This porous tissue is found inside the bones and provides strength and flexibility while minimising weight. The gaps are typically populated with bone marrow and blood vessels (not shown here).

SPACE

SpaceX launch lights up the night sky

The rocket illuminating the Californian sky in an otherworldly display of ghostly glowing cloud

SpaceX's latest Falcon 9 rocket successfully launched Argentina's SAOCOM 1A Earth observation satellite into orbit on 8 October at 02:21 UTC from Vandenberg Air Force Base in California. Less than eight minutes after launch the rocket landed safely at a new rocket landing pad just 400 metres away, thereby becoming the first ever SpaceX landing on the West Coast.

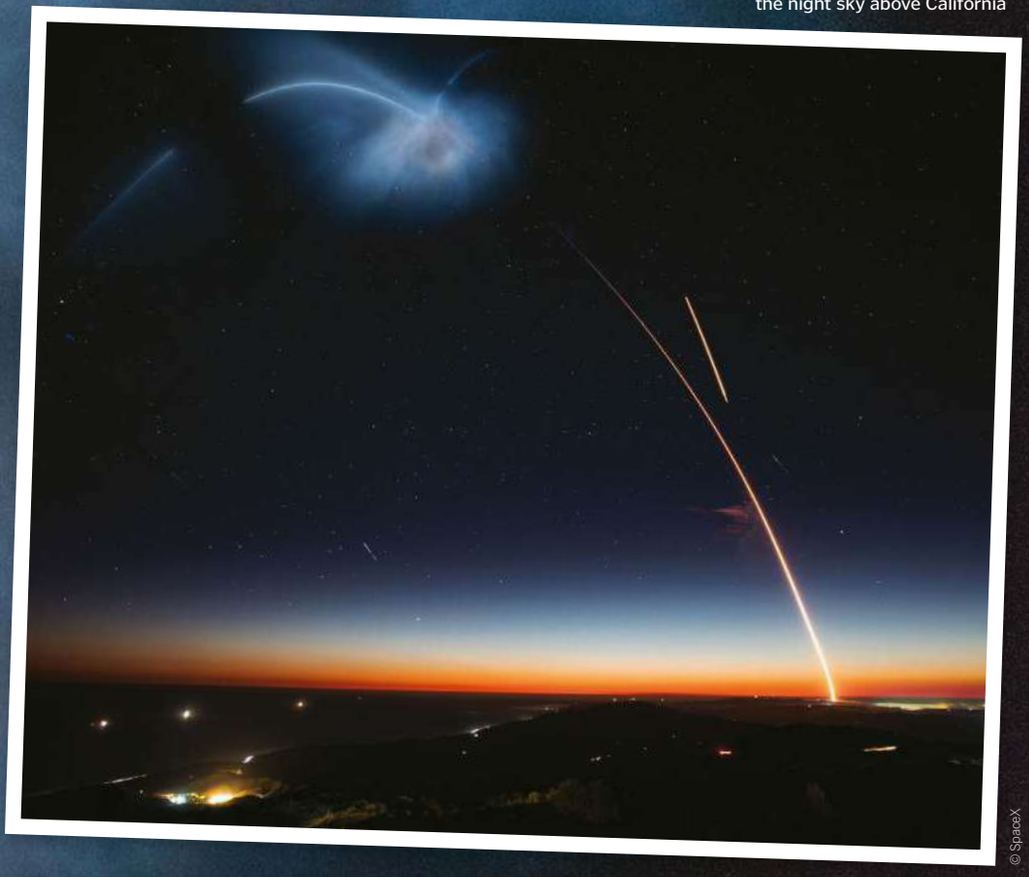
The launch created a nebula-like cloud in the skies above California as the high-altitude plume of rocket exhaust was lit by the setting sunlight. Los Angeles' mayor Eric Garcetti even took to Twitter to reassure everyone that the light source was nothing to be concerned about: "Nope, definitely not aliens. What you're looking at is the first launch and landing of the @SpaceX Falcon 9 rocket on the West Coast..."

The 1,600-kilogram SAOCOM-1A satellite is now in orbit 620 kilometres above Earth and will be using a Synthetic Aperture Radar (SAR) instrument to track soil moisture levels and aid in the forecast of crop yields. The data it collects will also help teams on the ground prepare for and monitor natural disasters like flooding and wildfires.

It was the second flight for this particular Falcon 9, which previously launched ten Iridium NEXT commercial communications satellites into low-Earth orbit from Vandenberg Air Force Base three months ago.

This successful landing is another huge step forward in SpaceX's mission to develop reusable rockets and thereby dramatically cut the cost of spaceflight.

The plume of smoke and rocket fuel created an eerie glowing cloud in the night sky above California



SCIENCE

First bioelectronic medicine revealed

The biodegradable implant uses electrical stimulation to speed up nerve recovery

The implant is the same size as a small coin

The implant slowly degrades inside the body after its job is done

Researchers at Northwestern University and Washington University School of Medicine have created a biodegradable implant that pulses with electricity to assist in healing damaged peripheral nerves in rats. The completely wireless device – as thin as a sheet of paper – has demonstrated promising results at improving the recovery of muscle strength and control. The implant is thin and flexible and can wrap around an injured nerve. It then delivers electrical pulses at specific times over the next few days. After about two weeks the implant is naturally absorbed by the body.

The invention is the first in a movement towards bioengineered medical technologies for humans. These are expected to provide therapy and treatment over a period of time directly at the site where it is needed in order to be effective and reduce the risks and side-effects patients face when having a permanent implant.

"These engineered systems provide active, therapeutic function in a programmable, dosed format and then naturally disappear into the body, without a trace," explained Northwestern University's John A Rogers, co-senior author of the study, in a press release. "This approach to therapy allows one to think about options that go beyond drugs and chemistry."

The technology has not yet been tested in humans, but the researchers are hopeful that it may offer a new option for nerve injury patients in the future. Electrical stimulation is already used during surgery and is known to aid recovery, but until now there has never been a way to supply the currents while healing is still in progress. This technology could revolutionise post-surgery recoveries.

"We know that electrical stimulation during surgery helps, but once the surgery is over the window for intervening is closed," commented co-senior author Dr Wilson Ray. "With this device we've shown that electrical stimulation given on a scheduled basis can further enhance nerve recovery."

HISTORY

Eight year old discovers pre-Viking sword

Saga Vanecek found an ancient sword while swimming in the Vidöstern lake in Sweden. The incredibly well preserved relic has been dated at about 1,500 years old.

SCIENCE

Genome editing cures mice

The metabolic disorder phenylketonuria, which can cause physical and mental developmental delays in children, has been cured in mice by using CRISPR technology to edit the mutated genes.

The latest report is the result of two years of research, during which time scientists examined over 6,000 different studies

ENVIRONMENT

Limit global warming to 1.5°C, says IPCC

According to the latest findings, the previously agreed two-degree limit may not be strict enough to combat the impact of climate change

According to the latest study by the Intergovernmental Panel on Climate Change (IPCC), curbing global temperature rises to just 1.5 degrees Celsius rather than two degrees by 2100 would have a significant impact. There would be fewer extreme weather events, less sea level rise and more species would be able to survive the resulting environmental changes.

195 nations signed the Paris Agreement in 2015, pledging to reduce greenhouse gas emissions in order to keep global warming below two degrees Celsius (compared to pre-Industrial temperatures) by 2100. It is hoped that the latest report will encourage governments to consider more ambitious emission-cutting targets.

SPACE

Suspected exomoon spotted

Kepler and Hubble have detected evidence of the first known moon outside our Solar System

NASA's Kepler and Hubble space telescopes may have found a moon orbiting the exoplanet Kepler-1625b, around 8,000 lightyears away in the constellation of Cygnus. Its presence has been detected in a similar way to how exoplanets are found via the transit method, where astronomers measure how much a star's light appears to dim when an object passes in front of it.

While further data is needed to confirm its existence, the initial findings suggest it's about the size of Neptune and may have formed through a completely different process to any of the moons we know of.

The Neptune-sized exomoon is thought to orbit a giant Jupiter-like planet in the Kepler-1625 system

SPACE

Construction of Europe's exoplanet hunter begins

ESA's Plato mission is set to study planets outside of our Solar System

At the 69th International Astronautical Congress in Bremen, Germany, the European Space Agency (ESA) announced that construction of their new space venture has begun. The PLAnetary Transits and Oscillations of stars (Plato) mission will seek out undiscovered rocky planets orbiting Sun-like stars. In particular, Plato will be looking within the habitable zones of stars, in which liquid water can exist on a planet's surface. At the congress, German technology corporation OHB System AG were announced as the prime contractors of the project.

"Plato is a next-generation exoplanet mission that will monitor thousands of bright stars over a large area of the sky in search of tiny, regular dips in their brightness caused by transiting planets," said Ana Heras, Plato project scientist at ESA, in a press release. Plato will be able to record these 'dips' in light and locate the potential exoplanets passing through the Sun's light.

This interstellar investigator will be multipurpose; it will also investigate the host star of any exoplanets found. The star's mass, size and age will be measured upon any discoveries, along with any seismic activity in order for scientists to gain a better understanding of its evolution. Plato is predicted to be launched in 2026.

Plato has a planned launch of 2026 and is part of ESA's Cosmic Vision programme for space science

Plato, Cheops and Ariel

The Plato telescope will build on the data collected from the upcoming Cheops (CHaracterising ExOPlanet Satellite) mission, which is due to launch in 2019.

Cheops will be the first mission to use ultra-high-precision photometry to study solar systems that are already known to have planets. In particular, it will look for super-Earths and Neptune-like worlds.

Plato will be followed in 2028 by the Ariel (Atmospheric Remote-sensing Infrared Exoplanet Large-survey) mission, which will study the atmospheres of around 1,000 different exoplanet targets. Its goal will be to find out what these worlds are made of and how they evolved.

All three missions will improve our current understanding of other worlds outside our own cosmic neighbourhood.

The Plato mission aims to hunt down planets in distant solar systems

ENVIRONMENT

Chimps share food

New study reveals that these apes only share food with their friends

Sharing food in the animal kingdom is rare outside of mating pairs, however, a new study conducted by researchers from the Max Planck Institute for Evolutionary Anthropology in Germany has found that not only do chimpanzees partake in this rare behaviour, but they are also rather exclusive with who they share food with.

Researchers observed chimps at the Taï National Park in Côte d'Ivoire, West Africa, and found that they would only share food with their friends in the troop, despite harassment from beggars or those with high dominance status. A previous study conducted by this team of researchers revealed that while hunting for meat, a successful hunter in possession of the meat would share the kill with others as a reward.

Sharing is caring in chimpanzee society

TRANSPORT

Self-driving cars reach milestone

Alphabet-owned self-driving car company Waymo has reached the impressive milestone of 10 million miles (16 million kilometres) driven on public roads in the US since first taking to the streets in 2009.

HISTORY

Ancient city gets older

The ancient city of Koh Ker, Cambodia, was previously thought to have been inhabited for just 20 years in the 10th century CE before being quickly abandoned. However, researchers from the University of Sydney, Australia, have found evidence to suggest Koh Ker was in fact occupied at least as far back as the late 7th century CE.

SCIENCE

New technique for Lyme disease diagnoses

Findings published in the journal *Clinical Infectious Diseases* have revealed a new technique that can detect DNA or protein from the Lyme bacteria faster than the three-week antibody-based tests that are currently used.

TECHNOLOGY

Vodafone conducts first UK holographic phone call

Could the future of phone calls be holographic with the introduction of 5G?

At their headquarters in Newbury, UK, Vodafone received the UK's first holographic phone call from their Manchester offices. This on-stage spectacle was part of the telecom company's Future Ready Conference, where a whole host of technological innovations were on display.

The call was made to showcase the future possibilities of 5G and its speedy and hefty data connection. Currently, 4G download speeds reach around 50 megabits per second, whereas 5G promises speeds 100-times faster. This, alongside a reduced latency of 5G, is what enabled England and Manchester City captain Steph Houghton MBE to beam in from Manchester during the demonstration.

Calling one another through VR headsets could become the future of phone calls thanks to 5G. Vodafone currently has seven urban sites ready to transmit 5G and plans to open 1,000 sites across the UK by 2020.

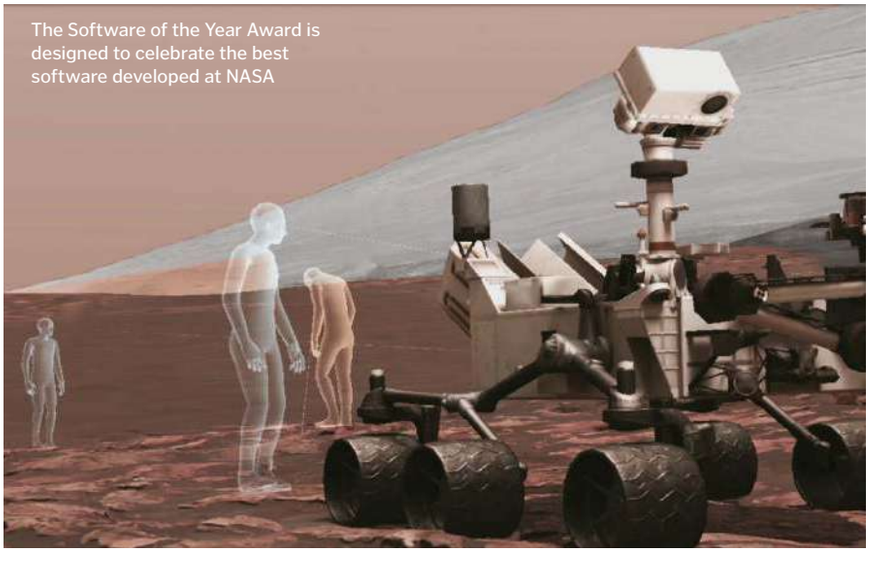
Footballer Steph Houghton made an appearance in holographic form thanks to 5G

SPACE

OnSight takes home gold

The virtual reality software OnSight has won the 2018 Software of the Year Award from NASA

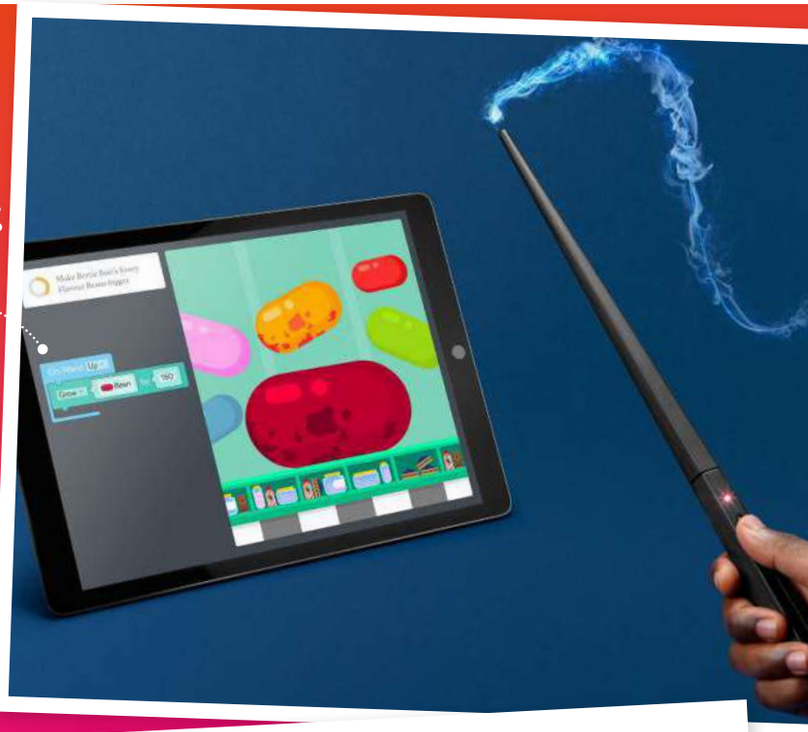
Collaboration between Microsoft and JPL's Ops Lab has resulted in the creation of the award-winning OnSight, a piece of virtual reality software that allows scientists to virtually experience the surface of Mars and study the terrain. The software uses images from NASA's Curiosity rover to recreate the surface of the Red Planet. It isn't just a solo experience either; avatars created within the software allow scientists to meet up and interact on a digital Mars.



The Software of the Year Award is designed to celebrate the best software developed at NASA

WISH LIST

The latest must-have technology



Harry Potter Kano Coding Kit

■ Price: **£99.99 / $99.99 / kano.me**

Kano have magically combined the world of Harry Potter and computer coding in their Hogwarts-themed kit. With a swish and flick of the coding wand, you can perform some digital magic.

After assembling the wand, witches and wizards can navigate through puzzles and challenges while learning how to use block coding. From casting wingardium leviosa to float feathers to stunning pesky pixies with stupefy, this coding kit brings learning to life by immersing the user in the wizarding world.

Upon completing challenges, the kit allows the player to go back and edit the block code and customise each game. Block coding allows the user to change or incorporate new things into the challenges, such as colour and wand movements. It's a great way for children to discover the limitless possibilities of coding while encouraging them to be creative.

FIND OUT HOW YOU CAN WIN THESE ITEMS ON PAGE 95!

Sphero BOLT

■ Price: **£149.99 / $149.99 / sphero.com**

Sphero have created another hi-tech robot that makes coding fun with the Sphero BOLT. Much like the other members of the Sphero family, BOLT can be controlled via the Sphero Play app to race around using the on-screen joystick. The BOLT can also act as a controller for games in the Play app, displaying interactive colours on its LED matrix.

The true potential of the BOLT, however, lies within Sphero's Edu app. Jam-packed with pre-programmed features to explore, the simple block code format allows users to edit pre-existing code or create their own. The BOLT can also communicate with other BOLTs via infrared sensors, so when two of them are together the pair can interact with more pre-programmed features, including acting out scenes that the user can write in block code. For those with more advanced coding abilities, the Sphero BOLT is also programmable via JavaScript.

Chem Lab C3000 chemistry set

■ Price: **£179 / $279.95 / brightminds.co.uk**

Our team love the Chem Lab C3000 kit. This isn't just any chemistry set though – it is one of the most sophisticated and advanced sets available on the market. If you want to start doing real science, the set guides you through over 300 experiments (that include working with real chemicals) and comes with all of the equipment and tools you need, including an alcohol burner.

This is an advanced kit for budding scientists, one made to a high quality, so you can learn proper chemistry techniques, particularly useful for a head start on the experiments you will be learning at secondary school. The very sophisticated set requires parental supervision for younger children to safely provide the fantastic hands-on approach to teaching chemistry.

The Chem C3000 kit comes complete with a 192-page full-colour experiment manual for easy-to-follow step-by-step instructions to perform each experiment.

Sega Mega Drive Classic Console

■ Price: **£59.99 / $51.99 / hawkin.com**

The Sega Mega Drive (known as Genesis to US gamers) returns. Simply connect this tiny console into your TV via an AV or composite socket to re-live a huge selection of timeless retro games. Enjoy over 80 built-in classics, including *Sonic*, *Mortal Kombat*, *Virtua Fighter* and many more. It may only be 14.5 centimetres wide, but there's still room for a cartridge slot just in case you have any old games stored away that you fancy re-playing. With two controllers you can play against friends and family on multiplayer games, just like old times!

Nerf Laser Ops Pro AlphaPoint Blasters

■ Price: **£44.99 / $44.99 / hasbro.com**

Hold your own laser tag battles with this pair of blasters from Nerf. No more firing foam rounds – this set brings play into the 21st century by shooting infrared bursts when you pull the trigger. That means unlimited ammo and no more hunting for lost foam bullets behind the sofa! Displays on each blaster show your health and ammo status, and quick reload buttons regenerate your firepower. You can also adjust the settings for indoor or outdoor play at the flick of a switch.

The pack includes armbands for each player, in which you can slot your phones to use the accompanying Nerf Laser Ops app, which gives you real-time battle info, lets you customise the blaster and even use GPS to track your opponents.

SmartGlobe Myth

■ Price: **£39.99 / $39.99 / oregonscientific.com**

Oregon Scientific is bringing the humble globe into the modern virtual world. The SmartGlobe Myth is the perfect learning tool to discover the world we live in. Using the accompanying app, you can bring the globe to life with augmented reality.

Hovering over Myth, smart devices will see animals, dinosaurs and landmarks spring from the planet's surface, helping you to learn about them. At the touch of a button Myth will reveal interesting facts about Earth and even tell a few fairytales. The interactive globe can also act as a night light, changing from continents to constellations.

APPS & GAMES

Transmission

■ Developer: **Science Museum**

■ Price: **Free / App store / Google Play**

Send information between transmitters and receivers in this puzzle game and create networks similar to those we use today, such as telephone networks.

Bee Factory

■ Developer: **Green Panda Games**

■ Price: **Free / App Store / Google Play**

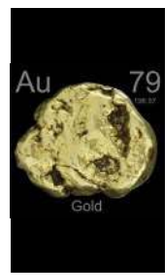
This addictive honey manufacturing game sees you manage your own bee factory and maintain the delicate balance between supply and demand. The more honey you make, the more wacky and wonderful the bees who come to help.

The Elements by Theodore Gray

■ Developer: **Touch Press Inc**

■ Price: **£8.99 / $8.99 / App Store**

This interactive periodic table of the elements reveals a wealth of facts and properties for each element. It also demonstrates how these elements have been used throughout the course of human history.

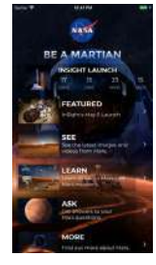


NASA Be a Martian

■ Developer: **Jet Propulsion Laboratory**

■ Price: **Free / App Store / Google Play / Microsoft Store**

Have you ever wondered what it would be like to explore the surface of Mars? You can find out using this app, which includes real images and videos from the Red Planet.



LIFE AT THE EXTREME

From volcanic ocean vents to the tops of the Himalayas, extremophiles have found ways to conquer every corner of the planet

Words by **Victoria Williams**

Although a few organisms with staggering survival skills have been known to us for centuries, the term 'extremophile' was first coined in 1974 by a scientist called R D MacElroy. It means 'extreme-loving' and refers to any form of life that thrives outside the narrow band of conditions humans can tolerate. Extremophiles have only been studied in detail for the last few decades, but they've already challenged many ideas we have about life and its limits.

Most extremophiles belong to the domain Archaea. These organisms consist of a single cell without a nucleus, and they're believed to be the oldest life forms on Earth, dating back billions of years. It's little surprise that these ancient species are the most tolerant and adaptable, since the young planet would have been a volatile and extreme place enveloped by a toxic atmosphere.

Today, extremophiles can be found all over the world in the most inhospitable environments; even the most desolate landscape is likely to be teeming with life invisible to the naked eye.

THERMOPHILES

In pools and springs hot enough to cause severe burns and even death to humans you'll find thermophiles feeding on the sulphur and ammonia in the blistering water. These microbes often produce pigments and lend their bright colours to the edge of the water. Heat-loving organisms have fatty acid linings in their cell membranes to stop them disintegrating at high temperatures.

At the bottom of the ocean, vents known as black smokers send out plumes of water and minerals reaching 400 degrees Celsius in temperature. The liquid doesn't boil because of the immense pressure it's under from the water above, but it still seems like the last place creatures would choose to live. Amazingly, it's not just microorganisms that can bear to be around these cracks in the

"An extremophile is any form of life that thrives outside the narrow band of conditions humans can tolerate"

Earth's surface; busy ecosystems develop and flourish around them, sustained by the nutrients leaking out from the planet's crust. Bacteria are the first to track down a new vent, followed by hardy bivalves like clams. Larger creatures like tubeworms and lobsters move in later, creating unusual communities that have amazed scientists since they were discovered in the 1970s.

CRYOPHILES

Frigid water, permafrost, mountain peaks and expanses of ice are havens for cryophiles. These organisms live in parts of the world that remain permanently cold and can withstand temperatures well below freezing, with some unicellular species still active at -25 degrees Celsius. Cryophiles, ranging from bacteria to deepwater fish, often produce antifreeze proteins to prevent ice crystals from forming in their bodily fluids.

As well as the freezing temperatures, cryophiles must contend with other stresses like high pressure and low oxygen levels on the seabed and high salinity in sea ice. When times get really tough, some cold-dwellers shut down their bodies and enter a state of dormancy until conditions become more tolerable again.

ACIDOPHILES AND ALKALIPHILES

While humans are best suited to a neutral pH between 6.5 and 7.5, acidophiles flourish in acidic environments where the pH is 5 or lower. Strong cell membranes keep them safe from the potentially damaging effects of acid, allowing them to live in sulphuric pools, polluted water and even human stomachs. Some aggregate for extra protection, forming slimy colonies called biofilms.

Alkaline conditions, at the other end of the scale, can be just as challenging. Alkaliphiles like *Spirochaeta americana* – bacteria found

"Busy hydrothermal ecosystems are sustained by the nutrients leaking out from the planet's crust"

Extreme enzymes

Enzymes are protein molecules that act as catalysts for chemical reactions in the body, and they're vital for keeping processes running smoothly. Most enzymes lose their structure and stop functioning – a process known as denaturing – when they reach the limits of their optimal ranges of temperature, salinity and pH. Extremophiles, however, have specialised enzymes, known as extremozymes, which are as well adapted to extreme environments as they are. For example, thermophile enzymes are compact, with a tightly wound structure to ensure they hold their shape under the effects of high temperature.

Extremozymes have been harnessed for use in industrial processes. While most enzymes can't cope with the harsh conditions, those derived from extremophiles work well and catalyse reactions to make the processes more efficient. Used in the manufacture of products from food to fuel, the global market for industrial enzymes has rapidly grown to billions of dollars.

Industrial enzymes have become big business

Earth's most extreme environments

Yellowstone National Park, US
Over half of the world's hot springs and geysers are in Yellowstone – paradise for thermophiles.

Atacama Desert, Chile
Bacteria have been found living among soil particles in the planet's driest desert.

Lake Retba, Senegal
This lake gets its famous pink colour from an algae species that thrives in its extremely salty water.

Antarctic ice sheet
Cold-loving organisms inhabit the tiny water-filled cracks in Antarctica's vast ice sheet.

Mount Everest, Himalayas
With freezing temperatures and a thin atmosphere, Everest is a challenging home for the spider *Euophrys omnisuperstes*.

Bacteria even inhabit the Atacama Desert, a region that receives an average of just 15 millimetres of rain each year

The bright colours of Yellowstone's Morning Glory Pool are also the result of bacteria

The Grand Prismatic Spring

The striking colours in Yellowstone's largest geyser are produced by different species of thermophile

Ring of fire
This outer orange ring is home to chloroflexi bacteria and *Synechococcus*, with both managing to get by in 65°C.

Clear blue
The water in the centre of the pool is the hottest, and bubbles at around 87°C. Unlike the other parts of the spring its colour is not the result of thermophiles – it's simply because the pool's water scatters blue light the most.

Mean green
Under other conditions, *Synechococcus* may appear blue-green thanks to chlorophyll, the primary pigment for photosynthesis.

Baking bacteria
A cyanobacteria called *Synechococcus* occupies the yellow ring at temperatures of around 74°C.

The soda cichlid swims happily in the alkaline waters of a soda lake

in salty, mineral-rich mud deposits at Mono Lake in California – cannot survive at a pH lower than 8 and do not need oxygen to respire. By actively driving certain molecules out of their cells in exchange for others, they can produce an internal pH closer to neutral than their surroundings and avoid any damage to their structure.

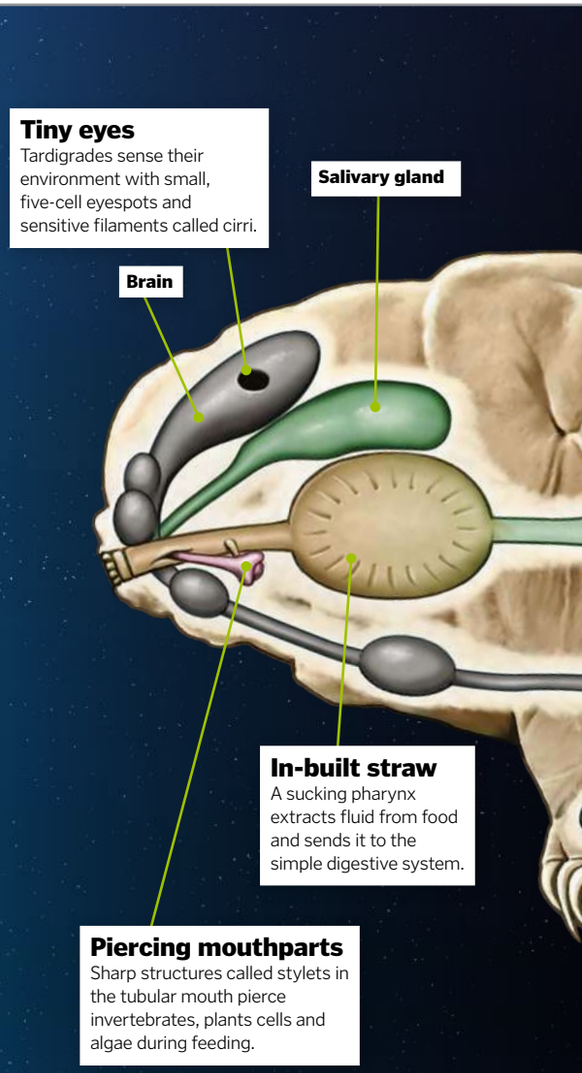
METHANOGENS

Methanogens are microorganisms that produce methane as a byproduct when their metabolic processes take place in low oxygen levels; living in oxygen-poor swamps and marshes, they're responsible for the bubbling that can be seen at the surface. Most people know that cows produce levels of methane harmful to the environment, but it's a lesser-known fact that the blame for this gas really lies with methanogens inhabiting the animals' guts.

Methane-emitting organisms have been found under kilometres of ice and in desert soil. The discovery of methanogens in arid environments is of particular interest to scientists; some believe that methane detected in the atmosphere around Mars could be a sign of microorganisms living on the Red Planet.

POLYEXTREMOPHILES

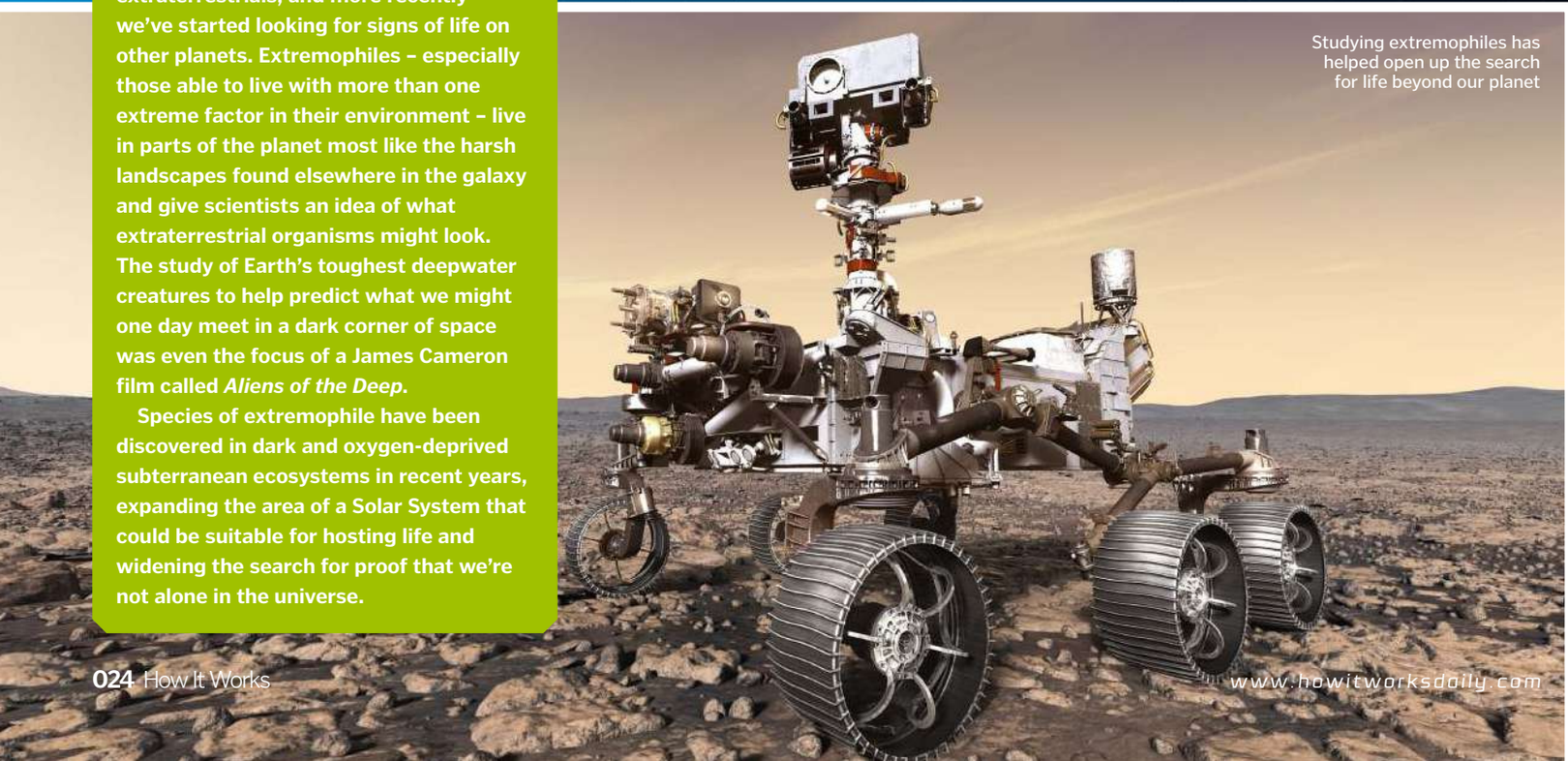
Few things in nature are simple or fit into neat categories, and there are extremophiles that require an even longer title than the others because they're adapted to live with multiple stressors. Take *Desulforudis audaxviator*; this bacteria lives 2.8 kilometres underground in groundwater in a South African gold mine, where it survives on chemicals released by the decay of minerals



Inspiring space exploration

For hundreds of years humans have been debating the possibility of extraterrestrials, and more recently we've started looking for signs of life on other planets. Extremophiles – especially those able to live with more than one extreme factor in their environment – live in parts of the planet most like the harsh landscapes found elsewhere in the galaxy and give scientists an idea of what extraterrestrial organisms might look. The study of Earth's toughest deepwater creatures to help predict what we might one day meet in a dark corner of space was even the focus of a James Cameron film called *Aliens of the Deep*.

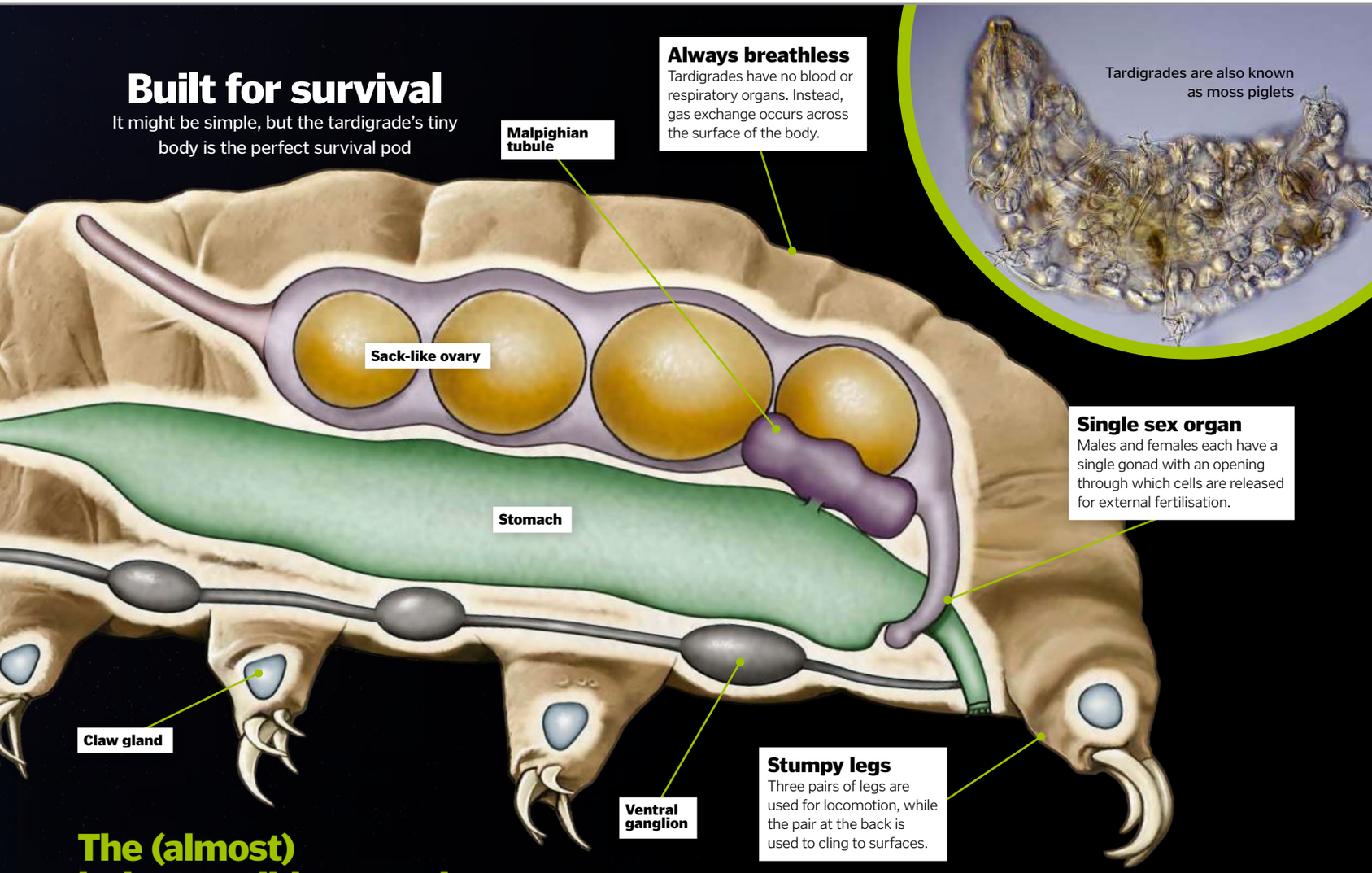
Species of extremophile have been discovered in dark and oxygen-deprived subterranean ecosystems in recent years, expanding the area of a Solar System that could be suitable for hosting life and widening the search for proof that we're not alone in the universe.



Studying extremophiles has helped open up the search for life beyond our planet

Built for survival

It might be simple, but the tardigrade's tiny body is the perfect survival pod



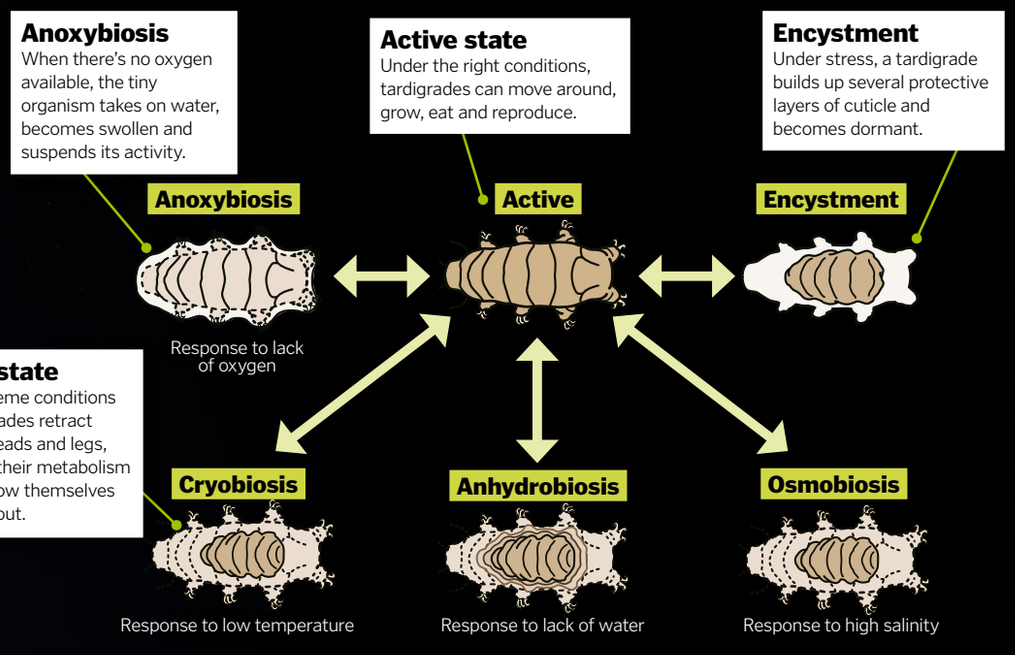
The (almost) indestructible water bear

Tardigrades, microscopic water-dwelling animals also known as water bears, are among the most famous survivalists in the world. Since they were first described by a German zoologist in 1773 they've been found in the depths of the ocean, at the top of Himalayan mountains, at the poles and in hot springs.

Despite this amazing resilience, they're technically not extremophiles. This classification is reserved for those creatures that exploit and thrive in extreme conditions, while tardigrades cope by suspending their metabolism and entering dormancy. During periods of drought, water content in the body drops to one per cent of the normal level. To prevent damage to the body, unique proteins take the place of lost water in the cells and become glass-like. In their dehydrated tun state some species of tardigrade are capable of enduring temperatures close to absolute zero and, though hot temperatures will eventually kill them, they can last for several minutes at 150 degrees Celsius.

With their metabolism barely functioning, starvation can be endured for years. They can also survive radiation levels hundreds of times higher than the dose that would kill a human and have even returned alive from a journey to the vacuum of space.

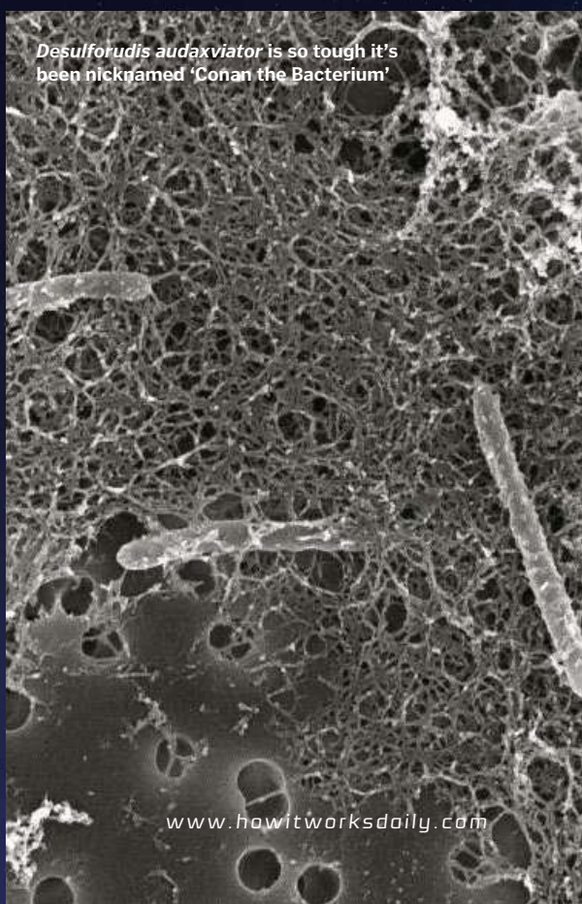
Many tardigrades can survive in this desiccated dormant state (known as cryptobiosis) for five years and will resume normal activity within hours of exposure to moisture. A few exceptional specimens have been 'brought back to life' after almost a decade, establishing tardigrades as some of the creatures most likely to survive a nuclear war or apocalyptic astrophysical event.



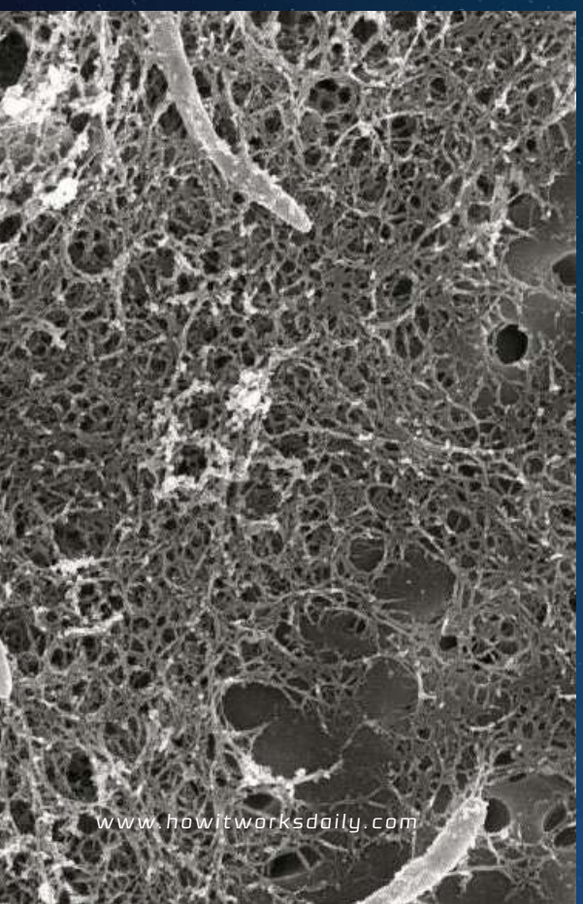
Bacteria and one hardy species of spider call Everest home

The bald notothen is a cod icefish native to the subzero waters around Antarctica

Scientists are studying extremophiles to better understand the origins of life and adaptations to extreme conditions



***Desulforudis audaxviator* is so tough it's been nicknamed 'Conan the Bacterium'**



in the rock. The groundwater is old and highly alkaline, and temperatures in the mine can reach 60 degrees Celsius. *D audaxviator* is the only known species that doesn't share its ecosystem with any other life form, and it's among just a few organisms that survive in the complete absence of light and oxygen. The name 'audaxviator' is a nod to its isolated subterranean life – it's part of an inscription found by the hero of Jules Verne's novel *Journey to the Center of the Earth* and means 'bold traveller'.

> "The world's toughest bacterium may help us develop a treatment for radiation exposure"

EXTREMOPHILES AND THE FUTURE

One of the reasons extremophiles are so exciting is that we still know relatively little about them. Every study into the hardy organisms reveals something new about their biology or the potential applications they could have in our lives. One extremophile found in stagnant water in an American cave system showed potential to destroy breast cancer cells. Another, *Deinococcus radiodurans*, is listed in the *Guinness Book of World Records* as the world's toughest bacterium; it's radiation- and acid-resistant and can survive vacuums and extreme cold. Its resistance to radiation is due to a set of antioxidants that protect its proteins, and researchers hope this knowledge will lead to the development of a recovery pill for people who have been exposed to radiation. On top of this, it produces proteins that emit infrared light. Scientists believe these fluorescent proteins could be used to light up cells and organisms and allow them to watch the processes taking place inside them for longer than is possible with the jellyfish proteins currently used by medical researchers and biologists.

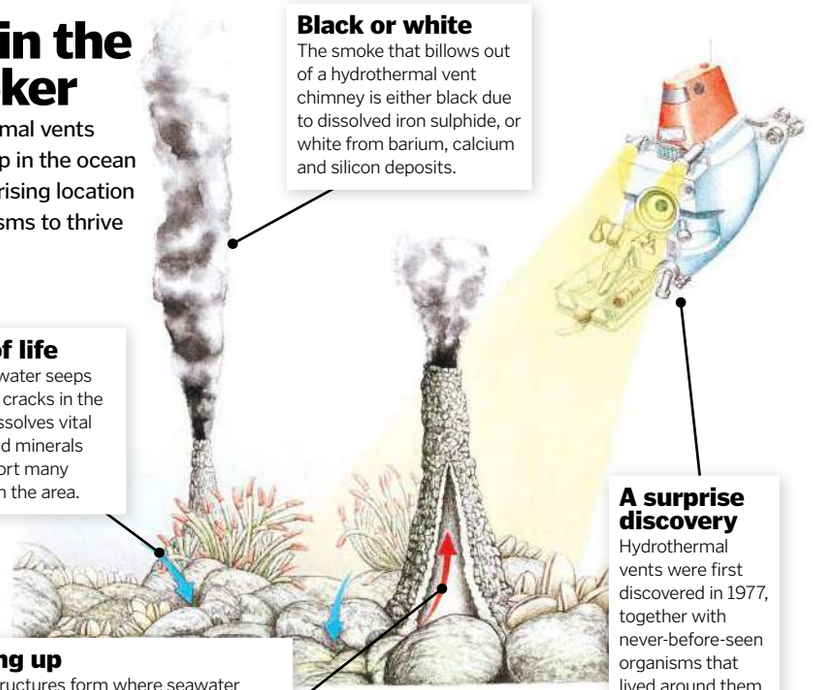
Extremophiles were around when the planet was still forming and cooling, and they might hold some of the secrets to protecting it. Since they thrive in the most hostile parts of the planet, they have evolved to use whatever is around them. Organisms like those that rely on iron to digest food have the potential to remove harmful metals and industrial waste products from the environment.

One microorganism discovered in Rotorua, New Zealand, in a geothermal field known as 'Hell's gate' prefers acidic conditions and survives solely on a diet of methane. This species could one day be used to reduce gas emissions from landfill sites and thereby help in the fight against global warming.

Given the rate at which they're now being discovered and the variety of abilities they possess, tiny extremophiles could soon be taking a big step into the spotlight.

Life in the smoker

Hydrothermal vents found deep in the ocean are a surprising location for organisms to thrive



How wells work

Groundwater is an important source of fresh water for people all over the world

Our planet has an abundance of water, and it is the source of all life on Earth, but when you pour yourself a refreshing drink of cold water from the tap, you probably don't think of the kilometres it has travelled from its source to your glass.

More than 70 per cent of our planet is covered in water, and a large portion of fresh water is stored beneath the surface as groundwater. This groundwater can be accessed by building wells – something humans first started doing around 8,000 years ago in the Neolithic period. These were mostly hand-dug wells, a method still relied upon by millions of people living in rural areas of developing countries. However, many hand-dug wells are now having pumps added to their systems or are being built deeper as a result of more sophisticated methods that make extracting the water a much more efficient process than it once was.

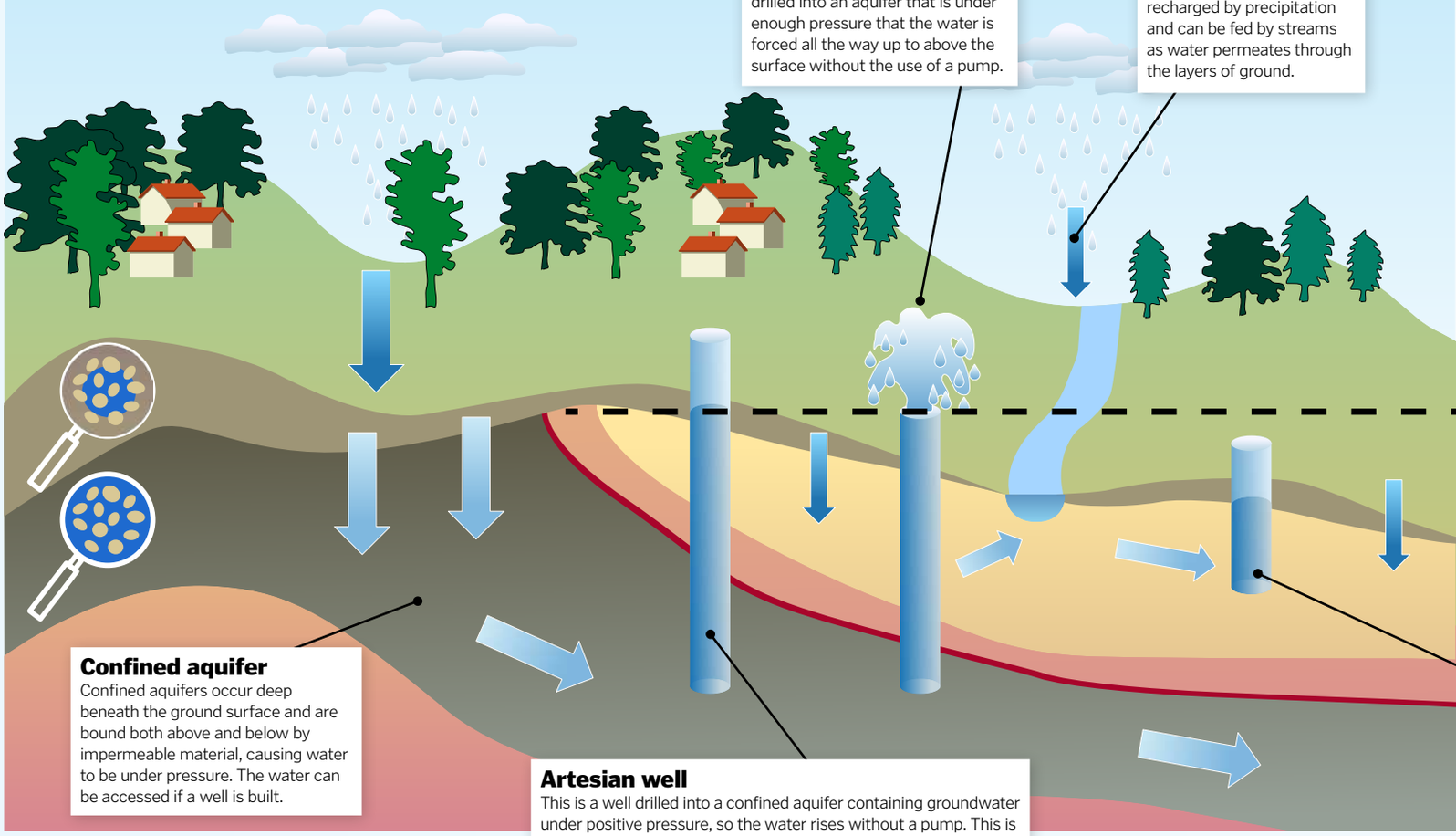
Wells accessing groundwater reservoirs provide 25 to 40 per cent of the world's drinking water. The reservoirs of water are stored under the surface in aquifers. Some aquifers are closer to the surface and are regularly replenished directly by rain (or melted snow) seeping into the ground, while others deeper in the ground may take longer to replenish as they gain their source from aquifers higher up. Many of these reservoirs were recharged in ancient times over thousands of years, making them renewable sources of water. Wells are built into these aquifers using different methods to access the drinkable water below.

Wells are particularly vital for those who live in remote villages without modern water supply systems

"More than 70 per cent of our planet is covered in water, and a large portion is groundwater"

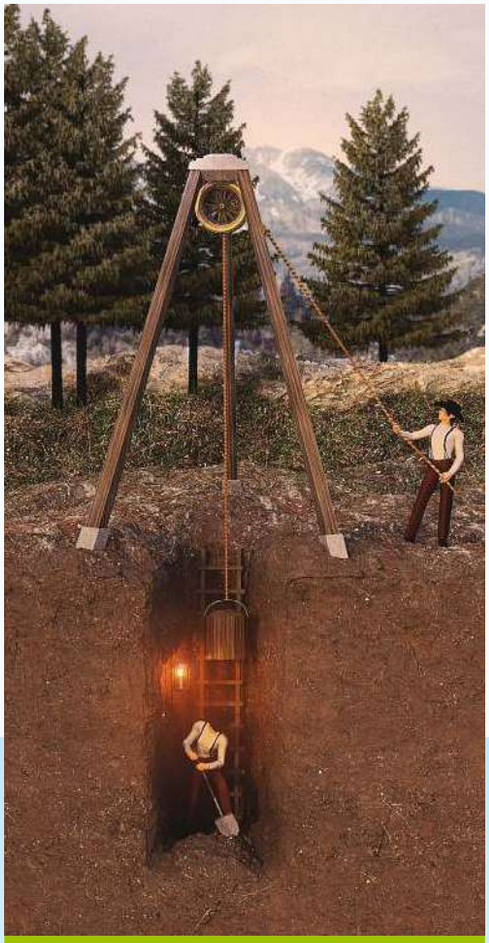
Wells, aquifers and groundwater

What underground water sources exist and how do we access them?



Building wells

There are three main ways to dig for water...



Dug

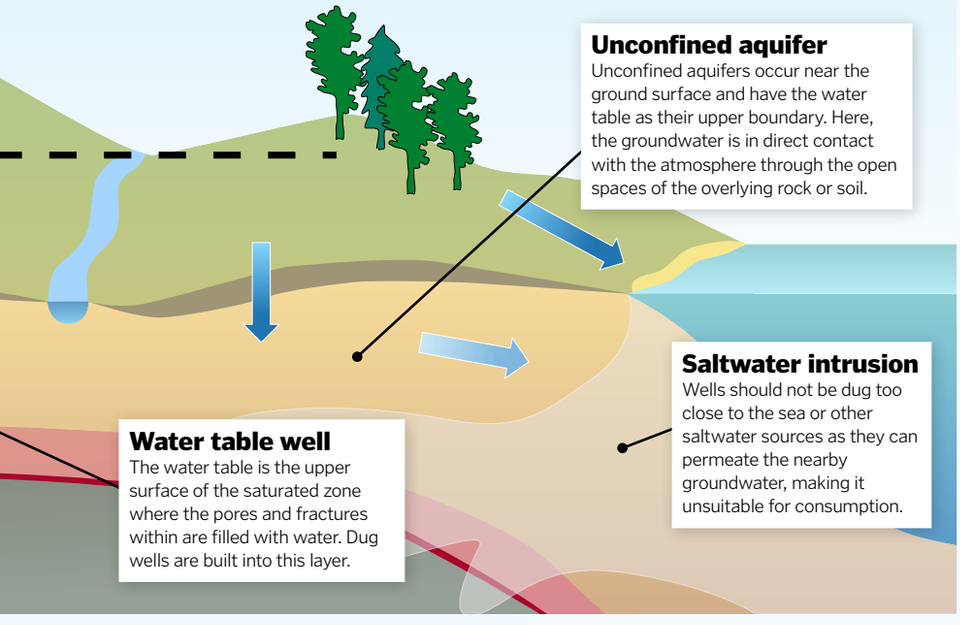
Dug wells are constructed below the groundwater table using a shovel. They are generally deepened until the digger finds water is filling the hole faster than they can bail it out. It is then lined with hard material to support it.

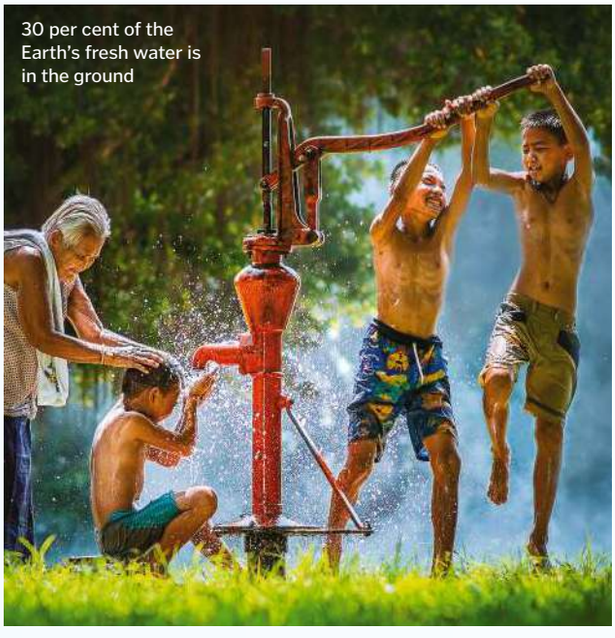
Driven

A driven well is smaller in diameter and built by assembling thin lengths of steel pipe. Each section – a couple of metres long – is screwed together and driven into the ground up to a depth of around nine metres.

Drilled

A drilled well is a hole bored into the ground. A lined casing is installed around the upper part of the well to prevent collapse and to stop surface or subsurface contaminants from entering the water supply.





30 per cent of the Earth's fresh water is in the ground

Earth in a bottle

Since the early 1990s Biosphere 2 has demonstrated the possibilities and shortfalls of creating a second home on Earth

Completed in 1991, it took four years to create Biosphere 2, an entire ecosystem modelled on the Earth. As climate change and extraterrestrial colonisation were hot topics of the time, the prospect of building a contained ecological system on another planet was at the forefront of engineer John P Allen's mind.

Allen conceived the idea of a human terrarium to study the effects of life in a bottle. Comprised of five biomes – an ocean with coral reef, tropical rainforest, savannah grassland, fog desert and mangrove wetlands – the project aimed to identify if these systems could work together to sustain life in confinement.

In order to create these ecosystems, samples of life from across the globe were taken and brought to Biosphere 2 in Arizona, US. This even included shipping tons of ocean water – rather than recreating water salinity artificially – so that algae and planktonic organisms could remain with the waters to provide their essential role in an ocean ecosystem.

Today, the 1.27-hectare bio lab is managed by the University of Arizona, who conduct experiments to better understand our changing global climate.

Biosphere 2 is now a research facility in Oracle, Arizona, in the US

Areas such as the tropical rainforest acted as an integral part of the Biosphere 2 ecosystem

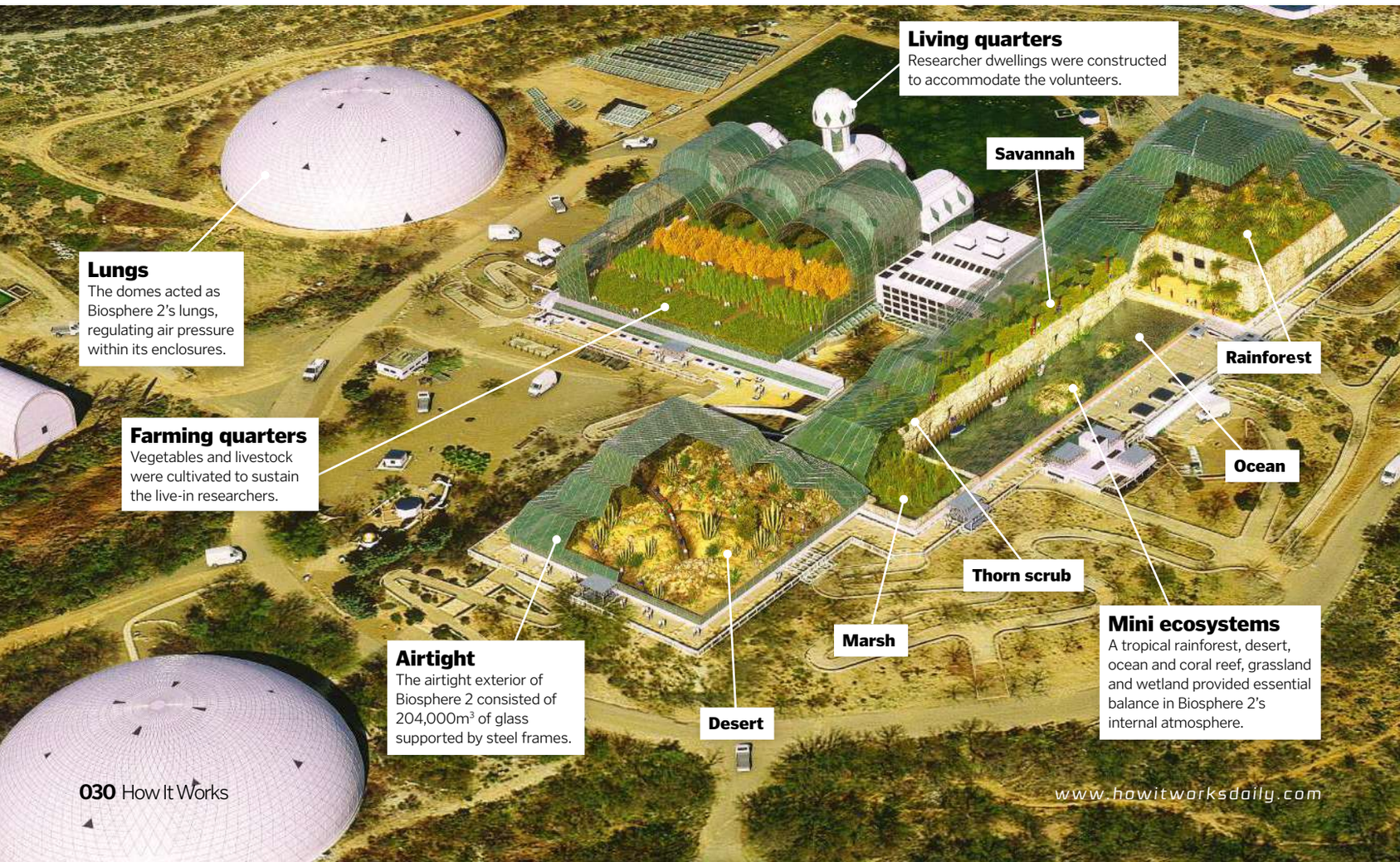
Biosphere Big Brother

To test the validity of an artificial ecosystem, in 1991 eight researchers stepped into the Biosphere 2 and remained inside for two years. The experiment allowed researchers to evaluate the potential of recreating an ecosystem. However, it was not plain sailing. Due to the highly fertile soil used in the agricultural sections, the balance of CO_2 and oxygen became wildly out of sync, resulting in the need for CO_2 scrubbers and oxygen injections to reduce dangerous levels of CO_2 filling the Biosphere 2. Even so, the experiment overall was a success.

Eight researchers spent two years testing the habitable limits of Biosphere 2 in the early Nineties

Building a biosphere

Discover how the Biosphere 2 sustained life within its walls



AIRFIX

QUICK BUILD

1	9.12 m	11.23 m
22.48 m²	2,182 kg	571 km/h
925 km	771 m/m	9,723 m

1 x Rolls Royce Merlin II V12

1	15.96 m	10.95 m
51.20 m²	11,15 kg	2,475 km/h
2,900 km	315 m/s	1.15

2 x Eurojet EJ200 Afterburning Turbofan

J6002 Typhoon

J6000 Spitfire

Aviation Royalty

AMAZING AIRCRAFT OF THE RAF

Throughout the 100 glorious years of the Royal Air Force the Supermarine Spitfire is arguably the most famous aircraft to ever wear the force's prestigious roundel. The Spitfire's sleek profile and distinctive wings making it a particularly beautiful aeroplane to look at, however, beneath this beautiful exterior lay a ruthlessly effective fighting machine that proved invaluable during the Battle of Britain and saw constant development throughout WWII, with over 20,000 aircraft eventually produced.

The Spitfire equivalent of today's Royal Air Force is the spectacular Eurofighter Typhoon, one of the world's most capable fighter aircraft, which possesses all the attributes that made the Spitfire so successful in combat. As the most effective air defence fighter to ever serve with the RAF, the Typhoon is destined to be protecting Britain's skies for many years to come and will hope to earn a reputation as remarkable as the Spitfire's.

You can you create your very own fighters of the RAF at home with an Airfix QuickBuild kit. QuickBuild kits allow you to recreate a wide variety of iconic aircraft, tanks and cars into brilliant scale models. No paint or glue is required, the push together brick system results in a realistic, scale model that is compatible with other plastic brick brands.

- ***Compatible with other plastic brick brands***
- ***Features a self-adhesive sticker sheet for authentic decoration***
- ***Includes a stand to show off your handy work.***

Collect them all! Check out the rest of the range online.

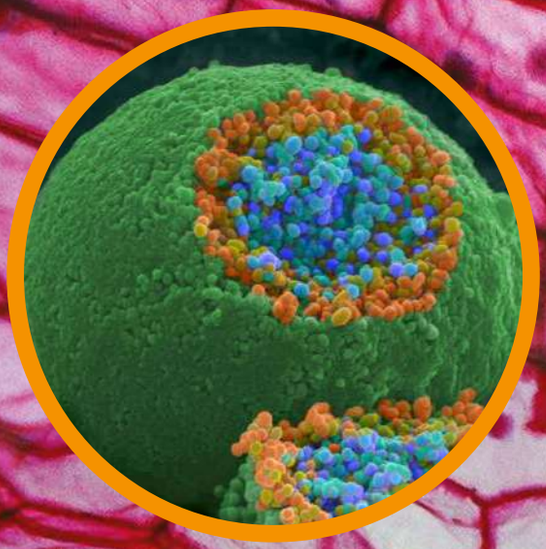
J6018 Red Arrows Hawk

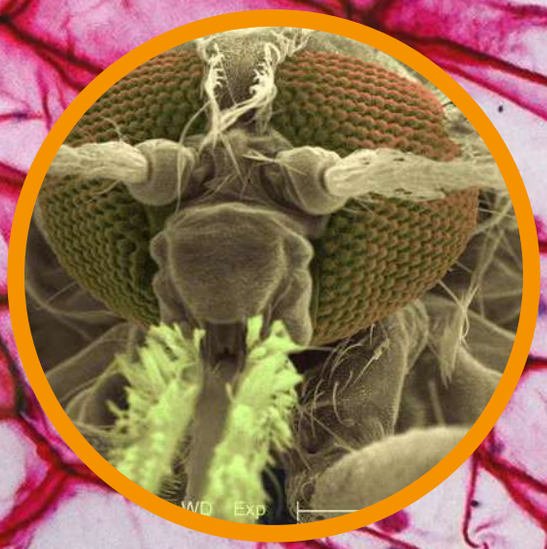
J6004 Apache

J6001 MESSERSCHMITT

Airfix.com and all good retail stockists YouTube

HORNBY HOBBIES
Official Product

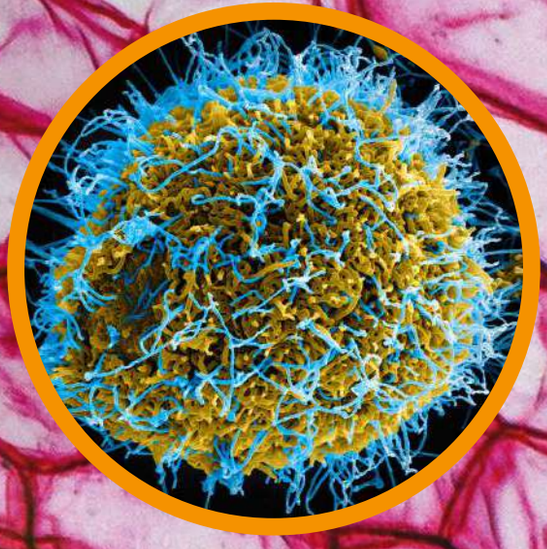




SMALL SCIENCE

How have microscopes revealed the tiny world around us?

Words by **Charlie Evans**



What is the smallest thing you can see? A grain of sand? The lines of your fingerprints? Or perhaps, if you look really closely, the diameter of a human hair? Throughout most of human history, our eyesight was one of the biggest limitations on scientific research. Because we couldn't see cells or bacteria or atoms, we had no concept of these things, and it wasn't until the invention of the microscope in the 17th century that we started to understand the invisible world around us.

Scientists started to discover germs swarming in drinking water and miniature animals in lakes, and later they began to learn more about our own anatomy, finding taste buds and blood cells. Over the next century microscope technology boomed. Scientists worked to develop microscopes that were powerful enough to help diagnose cancer, seek out evidence at crime scenes, and, later in the 19th century, discover the building blocks of everything in our universe – atoms. From the humble beginnings of the simple microscope to the development of the first electron microscope, today we have far more advanced technology that can even view the space between atoms.

> *"It wasn't until the invention of the microscope in the 17th century that we started to understand the invisible world around us"*

Microscopes are used to view and photograph very small objects that are invisible to the human eye. They can be categorised into two large groups: optical and electron. Optical microscopes are the ones you probably think of when you think of a microscope – they use a light source and a series of magnifying lenses so you can investigate your sample. This broad category is often used in diagnostic medicine and includes fluorescence microscopy, which observes fluorescence emitted by samples under special lighting, and laser microscopy, which uses laser beams to visualise samples.

Electron microscopes are even more complex, offering higher magnification and resolution. Instead of a beam of light, these pieces of equipment use a beam of electrons to create a projected image or record the bouncing back of electrons from the sample. There is also scanning probe microscopy, which includes atomic force microscopes that scan the surface of samples using a pyramid-shaped probe to map the surface of the specimen.

WHY DO WE NEED ELECTRON MICROSCOPES?

When you are looking at something really small, if you have enough light your eyes can distinguish two points that are about 0.2 millimetres apart. This means the resolution of your eyes are about 0.2 millimetres. Light microscopes have much better resolution, and electron microscopes even more so. This is because electrons have much shorter wavelengths than white light, which has wavelengths of about 400 to 7,000 nanometres. The beams of electrons in an electron microscope are nearer 0.1 nanometres. The smaller wavelength means less diffraction of

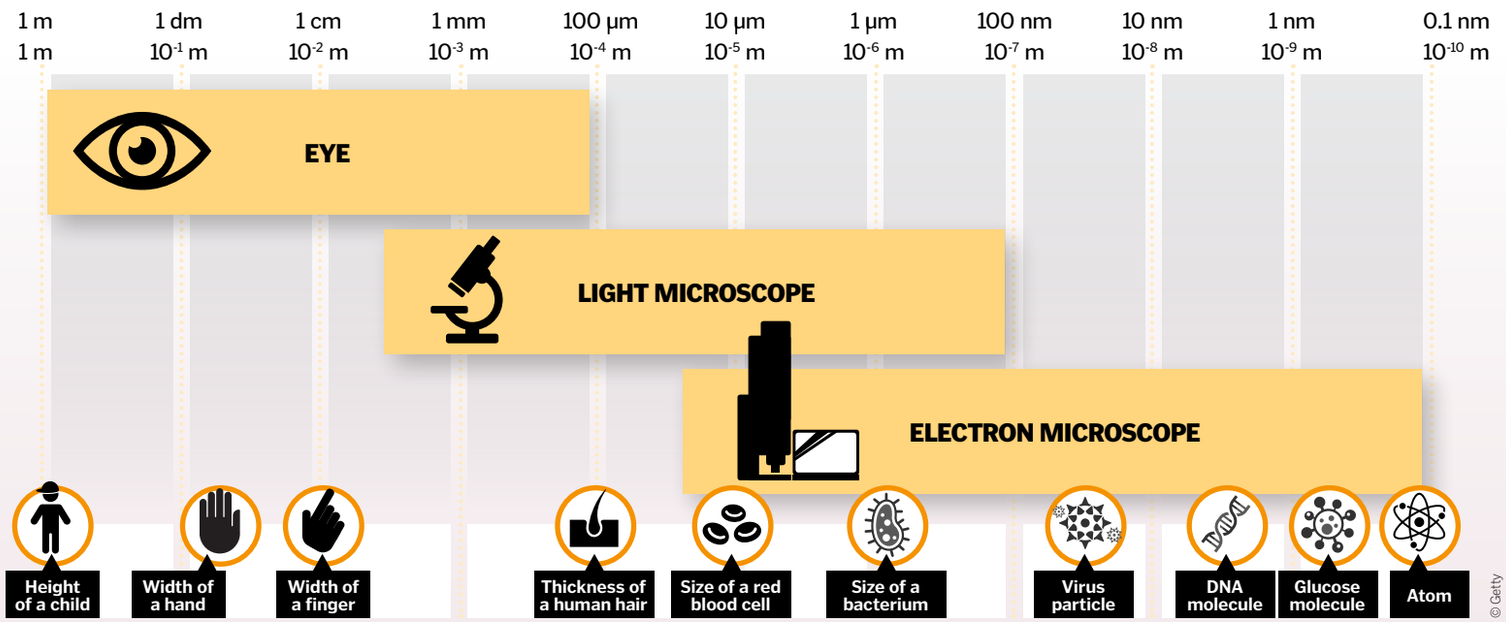
Who invented the microscope?

Like many inventions, trying to work out who was the first person to build a microscope isn't very simple. Historians are undecided on if it was Hans Lippershey (the person who patented the first telescope) or the father-son spectacle makers Hans Martens and Zacharias Janssen. All three lived in the same town in Middelburg, Netherlands. These first microscopes were quite simple; they were just a tube with a lens placed at each end but could achieve up to 9x magnification.

While Zacharias Janssen and his father claimed that Lippershey stole the idea from them, a view that was backed up by letters from the Dutch diplomat Willem Boreel, Zacharias was known to be a dishonest character who made a fortune from forging coins.

Hans Martens and his son Zacharias using an early microscope

UNDER THE MICROSCOPE Not even atoms can escape the glare of these tools



light being scattered in random directions and as a result a less 'fuzzy' and more precise image is observed.

As scientists learn more and more about the microscopic world and our technology gets smaller, many structures of interest to research and development cannot be observed with light microscopy any longer. We require higher power and higher resolution to create things such as the tiny microchips inside our smartphones, and electron microscopes are becoming more popular.

> "A high-voltage electricity supply powers the cathode, which generates a beam of electrons"

MICROSCOPES IN DIAGNOSTICS AND CRIME SCENES

While technology relies on electron microscopes, many fields of biology are reliant on optical microscopes, particularly when it comes to identifying disease. Researchers use optical microscopes in diagnostics to observe samples. This is because diseases often leave a path of specific changes to the cells that can give a clue to what is happening to a patient, like the trademark dark dots inside malaria-infected cells, or the big gaps between brain tissue infected with bovine spongiform encephalopathy (known as BSE, or the infamous 'mad cow disease').

Optical microscopes are also utilised a lot in the field of forensics, where investigators diligently search for even the tiniest clues left at a crime scene and need to magnify evidence such as fingerprints or fibres from clothing.

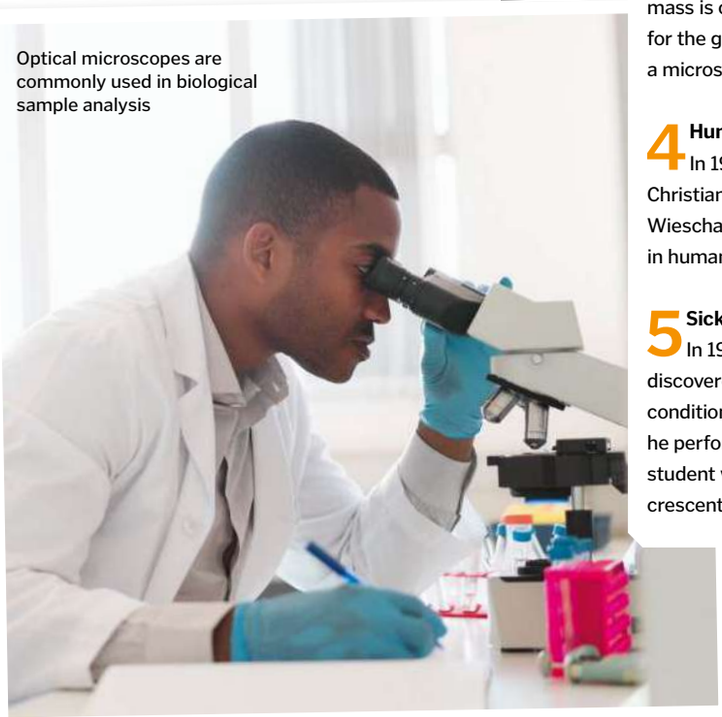
THE FUTURE OF MICROSCOPES

There are many ideas and inventions that were created over the last decade that are still being developed for use in industry. At the forefront of pioneering work to improve microscope technology is the University of Manchester. Teams there have helped to develop a record-breaking optical microscope that has brought biologists a step closer to being able to view live viruses (which currently can only be viewed under an electron microscope).

Electron microscopes can't take coloured photographs but they can be coloured artificially, like this image of red blood cells

Another project, launched in 2013 by the University of York, aims to combine the technology from optical and electron microscopes into one system in an attempt to overcome the challenges associated with both types.

It might be hard to predict the technologies of the future that are yet to be constructed, but one thing we can be certain of is microscopes haven't yet reached their full potential. Who knows what else we will discover?



Optical microscopes are commonly used in biological sample analysis

FIVE THINGS SCIENTISTS HAVE DISCOVERED THANKS TO MICROSCOPES

1 Bacteria
Antonie van Leeuwenhoek discovered bacteria and protozoa swarming in water during the late 1670s. He sent beautifully detailed drawings of them to the Royal Society in London.

2 Cells
Plant cells were discovered by Robert Hooke in 1665. He was looking at dead cells from cork and named them 'cells' because he thought they resembled 'cellula' (the small rooms in monasteries).

3 Atomic nucleus
In the Geiger–Marsden experiments, scientists discovered that atoms contain a positively charged nucleus where most of its mass is concentrated by watching for the glow of alpha particles with a microscope.

4 Human genes
In 1995, Edward B Lewis, Christiane Nüsslein-Volhard and Eric Wieschaus find the genes involved in human development.

5 Sickle cell anaemia
In 1910 intern Ernest E Irons discovered the painful inherited condition sickle cell anaemia after he performed blood work on a student who had anaemia with odd crescent-shaped red blood cells.

Big micro moments

Microscopes have come a long way

750–710 BCE
The Nimrud lens is created from a rock crystal disc with a convex shape and used for burning (by concentrating the Sun's rays) or for magnification.

1200s
Using lenses in eyeglasses becomes common practice and single lens magnifying glasses become popular.

1619
Date of earliest description of a compound microscope after Dutch ambassador Willem Boreel sees one in London belonging to inventor Cornelis Drebbel.

1655
The first record of claims that Hans Martens and Zacharias Janssen invented the compound microscope in 1590.

1665
Robert Hooke publishes a collection of biological photographs in *Micrographia* and pioneers the word 'cell' for the shapes he finds in bark.

1673
Antonie van Leeuwenhoek improves the simple microscope in order to see biological samples. He later observes bacteria.

Meet the microscopes

These machines use different techniques to let us see some of the smallest objects in our universe

Optical microscopes

Optical microscopes use light and a series of magnifying lenses to view specimens such as blood or tissue cells. They're probably the sort of microscope you used during science class at school. While they are the oldest microscope design, they remain vital in biological research and medical diagnostics.

Advantages

- Researchers can see the natural colour of the sample.
- Samples can be living or dead.
- Optical microscopes are not affected by magnetic fields.

Disadvantages

- The preparation to make a sample may distort specimen.
- Magnification is limited to 1500x.
- The resolving power (the distance needed to distinguish two points) for biological specimens is only around 1nm.

Scanning electron microscopes

Scanning electron microscopes use a beam of electrons that are scanned over the surface of a sample, which causes the production of secondary electrons, backscattered electrons and characteristic X-rays. These microscopes are held in vacuum chambers to prevent the electrons from hitting air molecules, and modern full-sized SEMs can provide a resolution between 1–20nm.

Advantages

- Minimal preparation of samples is required.
- Can provide detailed, three-dimensional and topographical imaging.
- Works fast and provides images within minutes.

Disadvantages

- Samples must be solid and able to tolerate vacuum pressure (not suitable for biological samples).
- Risk of radiation exposure due to the scatter of electrons from beneath the sample.
- Complicated and expensive, they are large and sensitive to electrical, magnetic and vibrational interference.

Transmission electron microscope

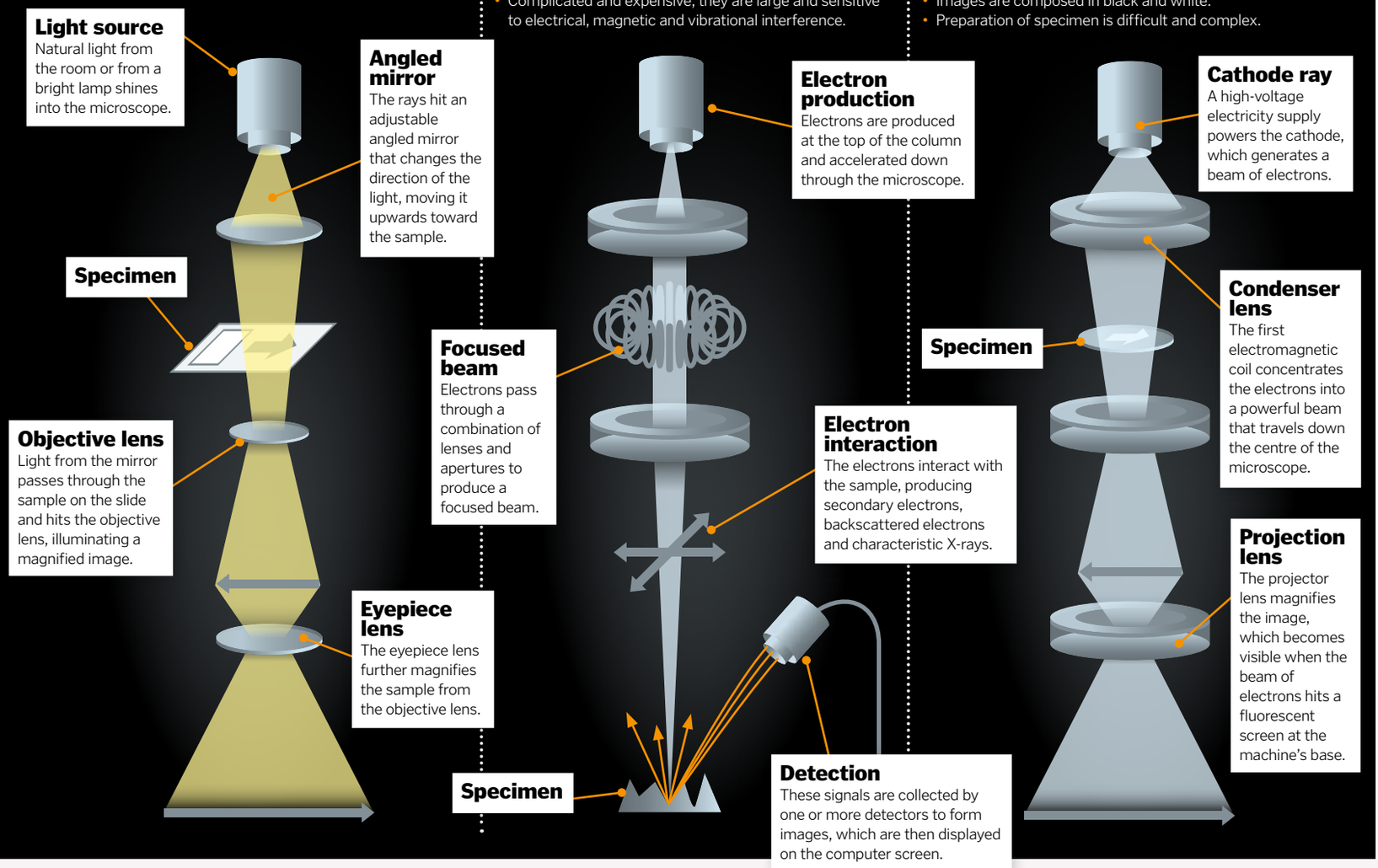
Transmission electron microscopes are the most powerful microscopes we have today. The electrons pass through the sample and are focused to form an image on a screen or onto a photographic plate. The faster the electrons hurtle down the microscope, the smaller the wavelength and the more detailed the image.

Advantages

- The most powerful microscopes, they can magnify by over 1 million times.
- Provide information on the element and compound structure of samples.
- Can determine shape and size as well as structure and surface features.

Disadvantages

- Samples must be 'electron transparent' (a thickness less than 100nm).
- Images are composed in black and white.
- Preparation of specimen is difficult and complex.



1873
The Abbe sine condition is discovered by Ernst Abbe, a requirement that a lens needs to satisfy if it is to form a sharp image that is free of any distortions.

1951
The field ion microscope is invented by Erwin Wilhelm Müller, making viewing atoms possible for the first time in history.

1953
Professor of theoretical physics Frits Zernike receives the Physics Nobel Prize for inventing the phase-contrast microscope.

1967
Erwin Wilhelm Müller builds on his original field ion microscope and creates the first atom probe, which allows the chemical identification of individual atoms for the first time.

1991
The use of the Kelvin probe force microscope is published and is able to observe atoms and molecules.

2008
Lawrence Berkeley National Laboratory installs a new $27-million microscope with a resolution of half of an angstrom. It remains the most powerful microscope.

Super STEM UK

A laboratory in Daresbury hosts some of Europe's most powerful microscopes

Some of the most powerful microscopes in the UK can be found in the countryside town of Daresbury, Cheshire. It's home to the UK National Facility for Advanced Electron Microscopy is funded by the Engineering and Physical Sciences Research Council (EPSRC). Here, researchers from all over the world come together to use the powerful microscopes that are kept at the facility. The newest model is the Nion UltraSTEM 100MC 'HERMES', also known as SuperSTEM 3, but the institute also houses the older models Nion UltraSTEM 100 (SuperSTEM 2) and the VG HB501 microscope equipped with a Mark II Nion C_s corrector (SuperSTEM 1).

These microscopes are a specialised type of TEM called scanning transmission electron microscopes (STEM), however, the 'HERMES' microscope can be used as a conventional transmission electron microscope (CTEM) as it is fitted with additional scanning coils to allow it to switch between different modes. The STEM machines produce images by using a focused beam of electron that scans across a thin sample in a raster pattern (horizontal, almost overlapping lines across a rectangular shape). The machines are so high resolution that they require an incredibly stable environment free from vibration, temperature fluctuations and electromagnetic and acoustic waves. This sensitivity can be demonstrated by clapping near SuperSTEM 2. The interference is immediately registered on the computer and jolts the atoms to one side.

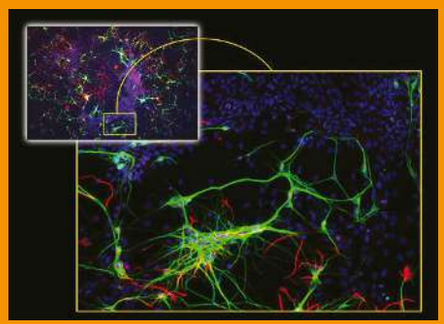
While the SuperSTEM1 requires only a basic level of stability and atmospheric monitoring, the SuperSTEM 2 is shrouded in a heavy, thick curtain to reduce interference. The SuperSTEM3 is so sensitive that it must be operated from a separate room.

The SuperSTEM facility is keen to provide access for the global scientific community. Previous projects include investigating thermoelectric oxides for power generation and looking at molybdenum disulphide, a catalyst used in oil refineries, to remove harmful sulphur impurities in fossil fuels. Researchers from all fields are invited to apply to use the microscopes in small studies free of charge pending review by the scientists at the facility.

The Mesolens microscope

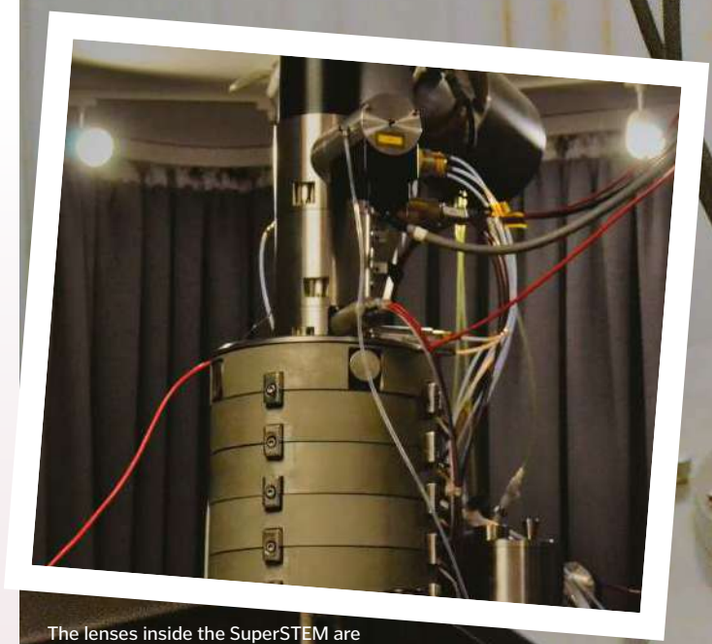
Modern optical microscopes have to compromise between the level of detail they can provide and the amount of sample they can show at a time. The giant Mesolens was created to overcome this limitation as it is designed to have both high resolution and a wide field of view. This powerful microscope lens is able to view both densely packed cells and the entirety of an embryo in one image, and it can magnify samples by up to 4x higher detail compared to conventional counterparts that produce the same magnification.

The Mesolens has meant researchers are able to observe cells in situ complete with blood vessels and other surrounding tissue and can process a volume of sample 100x greater than when using a conventional microscope.



A culture of rat brain cells stained with fluorescent dyes including neurons (green), glial cells (red) and the nuclei (blue) of astrocytes

The SuperSTEM 1 is the oldest model of microscope at the facility and is an upgraded version of one of the machines built in 1970



The lenses inside the SuperSTEM are stacked to condense the beam

The SuperSTEM 2 is operated behind a curtain to protect experiments from interference due to temperature fluctuations or vibrations in the air

"The Mesolens has meant researchers are able to observe cells in situ, complete with blood vessels and other surrounding tissue"

An interview with SuperSTEM's Demie Kepaptsoglou

How It Works interviews one of the scientists behind the project to uncover the universe's atomic secrets

There must have been some incredible things you've seen under these microscopes. What has been your favourite?
There's so many! Graphene, obviously. I remember the first time I looked at graphene. That was very cool because it's just a single atom thick and I was able to distinguish each atom. But also we have a collaboration with colleagues in Germany and they bring me meteorites that have travelled the universe – some of them are 4.5 billion years old. I was surprised to find out there is organic material in meteorites – there is this theory that it could be how the first organic matter came to Earth. There is a saying we have: 'We are investigating the universe, one atom at a time, but it might take us a while to get there.'

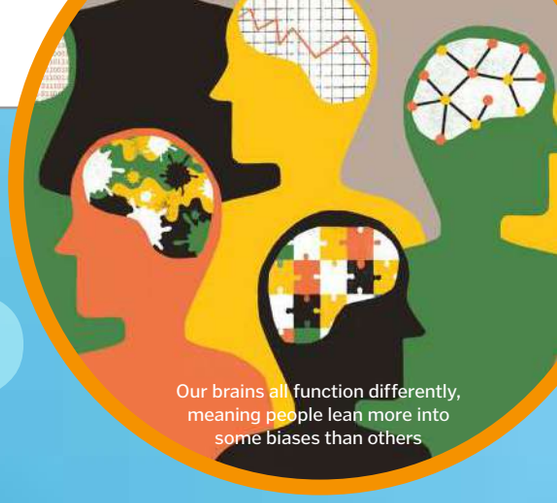
What is the importance of understanding the materials around us on an atomic level?
Do you remember the phone batteries that were exploding? These are batteries that are very, very small but are as powerful as a computer ten years ago. Obviously there was some fault in the production but it might not have been large at all because the products are so small now. We don't realise how much work and research goes into our everyday products.

Are there any advancements that you are excited to see in the future that will need electron microscopes?
I think drug delivery systems that will involve atoms and subatomic particles. There has been research into attaching magnetic nanoparticles to drugs so that they can use a magnet to guide the drug where they need it, [towards a] tumour or something.

Are nanoparticles dangerous to our health? Can you use electron microscopes to investigate this?
Yes, I was involved in an atmospheric study and they were collecting nanoparticles on the side of the road. They were determining what kind of nanoparticles were in our air and they found a lot of iron oxides coming from the brakes of cars. Understanding what things look like and how they act is very important to understanding the impact [of small particles] on health.

How much can you trust your brain?

Our decisions are not always our own thanks to the unconscious biases buried in our brains



Our brains all function differently, meaning people lean more into some biases than others

Bandwagon effect
People follow the crowd, meaning you might be more likely to vote for someone because they have more supporters even if they don't align with your views.

Conservatism bias
Have you ever heard someone say, 'There's nothing that will change my mind'? That is conservatism bias. We have a tendency to not update our views when faced with new evidence.

Confirmation bias
When you believe something to be true, you see evidence that supports it, like when you think someone doesn't like you, you are more likely to notice when they're 'off' with you.

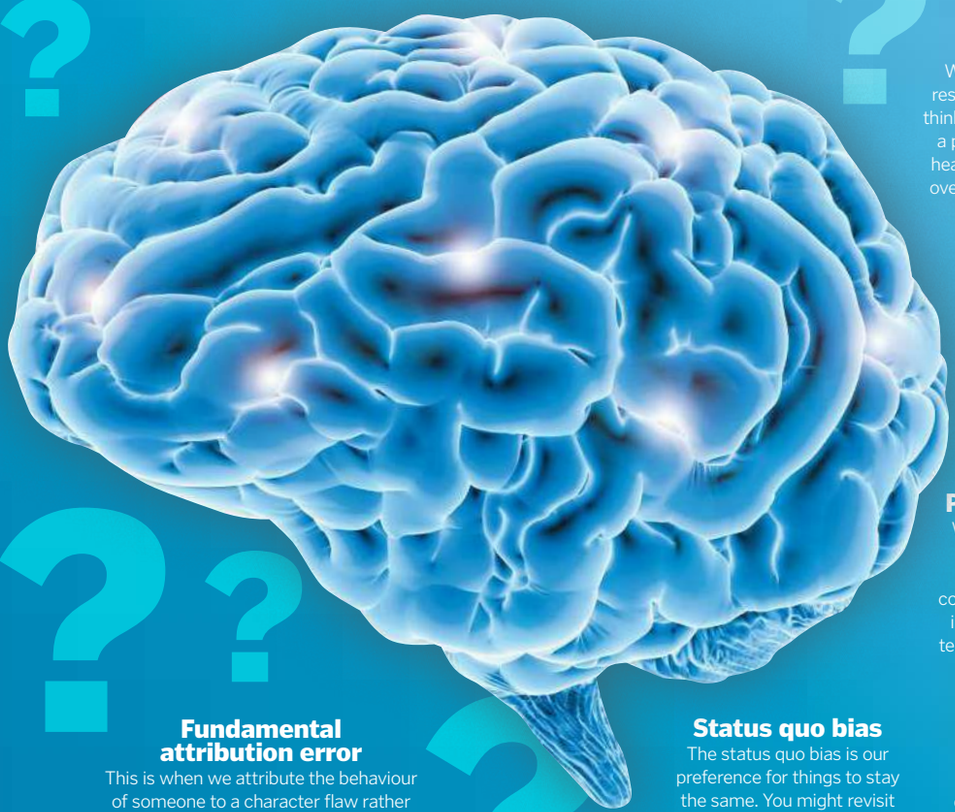
Empathy gap
When we are being logical (cold), we don't understand how our decisions would differ if we were emotional (hot). Conversely, when we are emotional we don't realise how much our decisions are being influenced by emotion.

Anchoring bias
We make our decisions from the first piece of information that we learn about a subject. This is why we are more inclined to buy something when we see the original price placed next to the reduced price.

Choice-supportive bias
When you make a choice, it is probable you will look back on it positively to rationalise your decision, even if you see afterwards that there were better options.

Negativity bias
Negativity bias is when our minds react more strongly to negative experiences rather than positive ones. It makes us more likely to turn down opportunities because we can see the threats within the choice rather than the advantages.

Frequency illusion
Have you noticed that when you learn a new word you start seeing it everywhere? Our brains have a habit of trying to see patterns, so we notice things more if they are interesting to us – like a new word.



Restraint bias
We overestimate our ability to resist temptation. This means we think we won't eat a slice of cake at a party when we're trying to eat healthily, but many of us will have overestimated our own willpower.

Ostrich effect
Humans often (metaphorically) bury their head in the sand. We choose to ignore the bad things that are happening, like not checking our bank accounts, rather than tackle the problem.

Galatea effect
This describes the power of self-expectation. If you believe you will succeed you are more likely to be successful, compared to if you believe you can't do something.

Overconfidence bias
Some people may be overconfident in their abilities because of this bias and as a result take greater risks in decision-making, which may end positively or negatively.

Procrastination bias
We tend to accept short-term reward rather than wait for a better reward. We know our coursework will be more worth it in the long run, but we are still tempted by the funny cat videos.

Scope insensitivity
Our brains are not very good at understanding scale. If we hear a disaster has impacted 200, 2,000 or 200,000 people, we react the same because we can't comprehend the larger numbers.

Fundamental attribution error
This is when we attribute the behaviour of someone to a character flaw rather than just an uncharacteristic moment. Someone who snapped at you once is probably not an angry person, but we think they are.

Status quo bias
The status quo bias is our preference for things to stay the same. You might revisit the same restaurant or purchase the same brands just because that's what you have done in the past.

Reactance bias
If we are forbidden to do something, we may have the desire to do that exact thing in order to prove our freedom of choice, like being asked not to walk on the grass or touch a piece of art.

Selective attention
Our attention is a limited resource, and we have to direct it on things specifically for it to work. Our brains filter information in our environment to focus on what is useful and ignores the rest.

Zero-risk bias
We prefer the elimination of all risk over a greater reduction in a larger risk (overall), like choosing to clean up a small oil spill completely, rather than using the same money to clean up a giant oil spill significantly.

Survivorship bias
You see so many books every day, you might think it is easy to publish. This is an example of survivorship bias, as you have not seen the many more that didn't make it to the publishing stage.

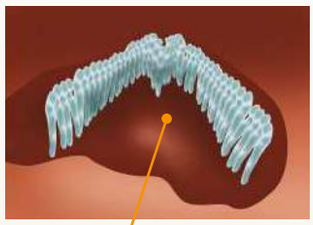
The dangers of loud noises

How can high-volume sound cause hearing loss?

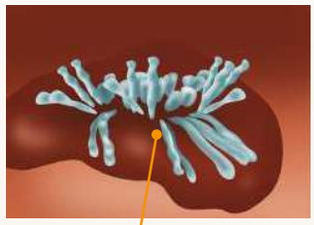
The way we hear sound involves an intricate series of physical, chemical and electrical activity within our ears. An integral part of our ability to hear lies in the tiny hair-like cells within the cochlea. As sound vibrations enter the ear, these cells - called stereocilia - will bend. This bending action opens pores within the cells, allowing ions into the cells and creating an electrical charge to stimulate our auditory nerve so sound can be perceived. Once the sound stops the hair-like cells will spring back into a straight position. These stereocilia cells, however, are delicate structures that when damaged can start a domino effect leading to hearing loss. Loud noises are one of the ways these tiny cells can lose their bounce.

Noise-induced hearing loss (NIHL) can be caused by either a single exposure to a deafening sound or longer-term exposure to loud noise such as music. These exposures will damage the stereocilia's ability to bend and ultimately limit if not remove the electrical signals sent to the auditory nerves and subsequently the sound being integrated by the brain. A normal conversation is held at about 60 decibels, but if exposed to sounds over 90 decibels every day chronic hearing loss may occur.

Keep it down!
The human threshold for hearing pain is 140dB. Anything above this level of noise causes discomfort.



Pre-concert
Before the band begins to play the sound-translating hair-like cells are active and stand relatively straight.



Post-concert
After being bombarded with sound, these cells wilt and in some instances are damaged, creating that post-party buzzing sound.

Inside the ear

What happens to our ears when we listen to loud music?

Eardrums
Sound vibrations are sent through the eardrum and across three bones to the cochlea.

Pain
Nerves in the inner ear respond to higher decibels of sound in the form of pain.

Auditory nerve
The electrical signals generated from the cochlea are carried to the brain via the auditory nerve.

Switching electricity for light

Researchers at the University Medical Center Göttingen, Germany, have used optical fibre technology to restore hearing in gerbils, a breakthrough that could improve on current technology used to combat hearing loss, such as cochlear implants. These implants have revolutionised medical treatment for those who are hearing impaired. Modern-day cochlear implants convert sound into electrical signals in the same way as the natural ear but are still somewhat sensitive to all surrounding sounds. The German research team have taken on this challenge, and rather than producing an electric signal, their device creates light. With the aid of a virus-carrying gene encoding for light sensitivity, hearing-impaired gerbil test subjects were found to respond to sound with the use of the optical implant.

Cochlear implants artificially convert sound into electrical signals

The science of your skin

Lifting the lid on the body's largest and most sensitive organ

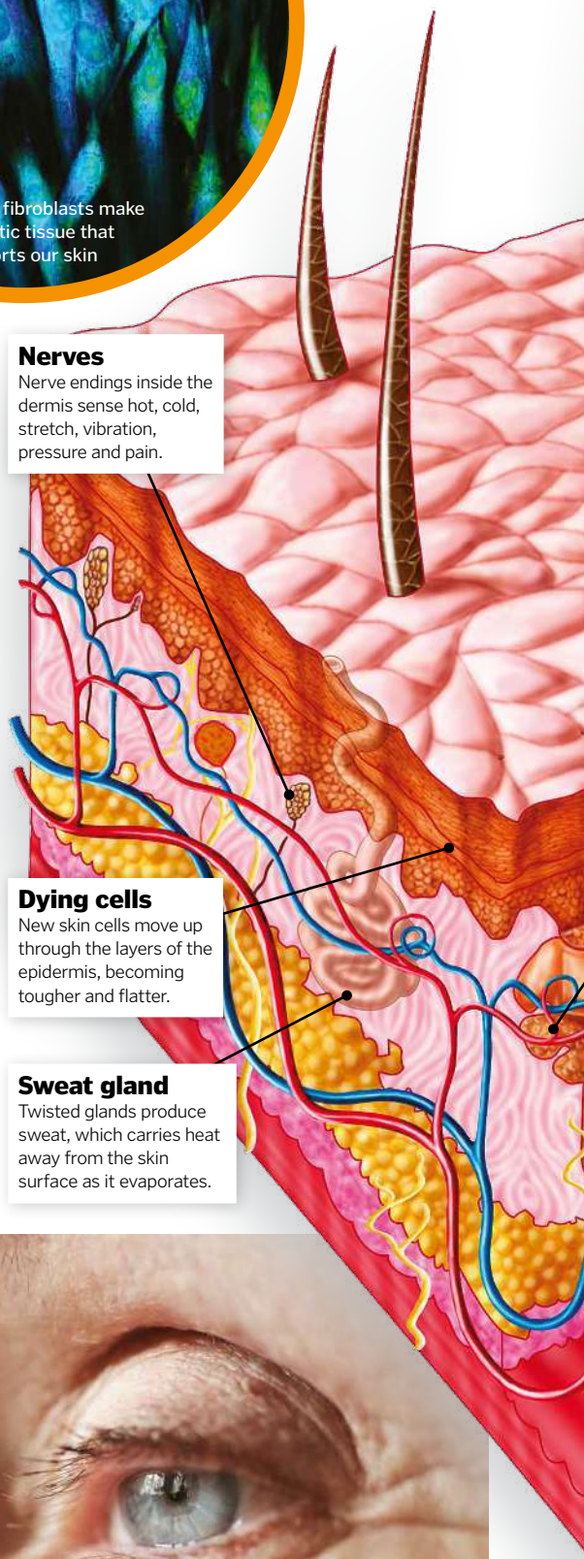
Cells called fibroblasts make the elastic tissue that supports our skin

Weighing in at 2.7 kilograms, your skin is by far the largest organ in, or rather on, your body. Wrapped around you from head to toe, it provides a waterproof barrier that separates your tissues from the outside world. Skin keeps moisture in, blocks out the light, stores fat, senses touch, regulates temperature and shields you against infection. To do all this it has three separate layers, each packed with a different set of specialist cells.

The outermost layer of the skin is the epidermis. It contains four or five layers of skin cells, which come from cube-shaped stem cells deep under the surface. These stem cells make enough new skin cells to completely replace your skin every four weeks. The skin cells themselves are called keratinocytes, because they make the protein keratin. This is the same tough fibre that makes hair and nails. As new keratinocytes appear, they push the old ones upwards and, as the cells get closer to the surface, they become flatter and tougher. The cells die as they reach the very outer layer, forming a hard and water-resistant barrier.

Collagen fibres connect the epidermis to the next layer of skin via a series of finger-shaped folds. This layer, called the dermis, contains blood and lymphatic vessels, nerves, hair follicles and sweat glands. These structures all sit in a layer of flexible fibres, which are made by specialised cells called fibroblasts. The fibres – elastin and collagen – give skin its strength and ability to stretch.

The very bottom layer of skin is the hypodermis, and it links the skin to the inside of the body, connecting it up with muscle, bone and tissue. Here, cells called adipocytes store excess energy as fat, providing a layer of insulation and cushioning against impacts.



Nerves
Nerve endings inside the dermis sense hot, cold, stretch, vibration, pressure and pain.

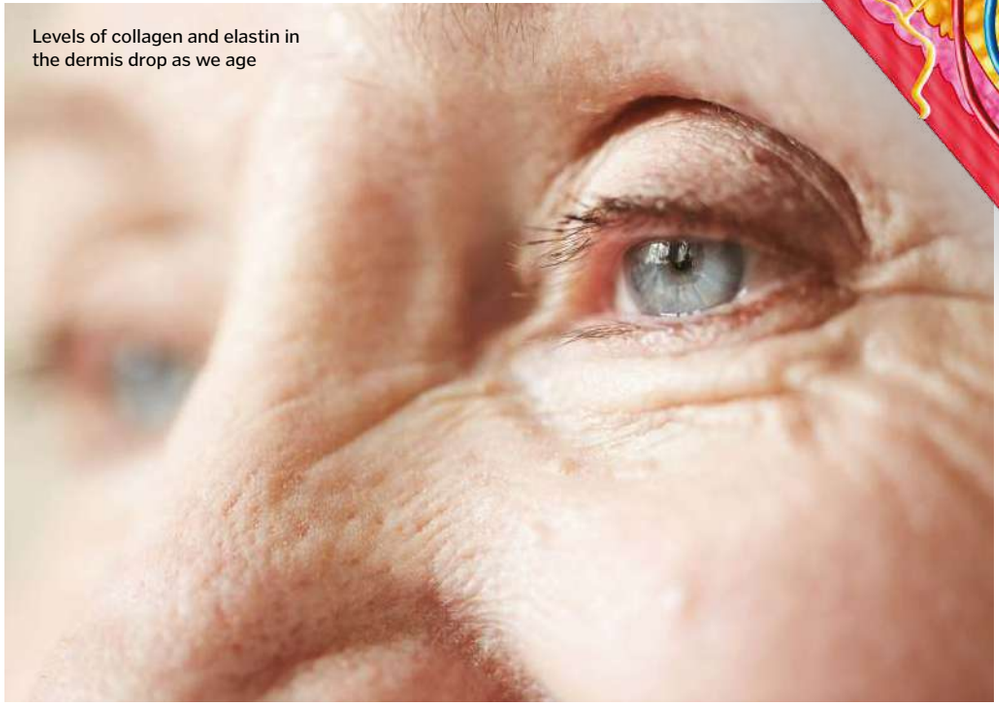
Dying cells
New skin cells move up through the layers of the epidermis, becoming tougher and flatter.

Sweat gland
Twisted glands produce sweat, which carries heat away from the skin surface as it evaporates.

Types of skin

Your skin might be one organ, but it's not the same all over your body; different zones vary in thickness, oiliness, sweatiness and hairiness. The palms of your hands and the soles of your feet have the thickest skin, with an extra layer of cells in the epidermis. They have fat pads under the surface and, though they don't make hair or sebum, they produce lots of sweat. Your armpits, in contrast, are very hairy and produce lots of oil, contributing to body odour. They also have a higher pH than the rest of the skin, making it much easier for bacteria to grow. The most delicate skin on your body is on your eyelids. At just 0.04mm thick it is 40-times thinner than the skin on the soles of your feet.

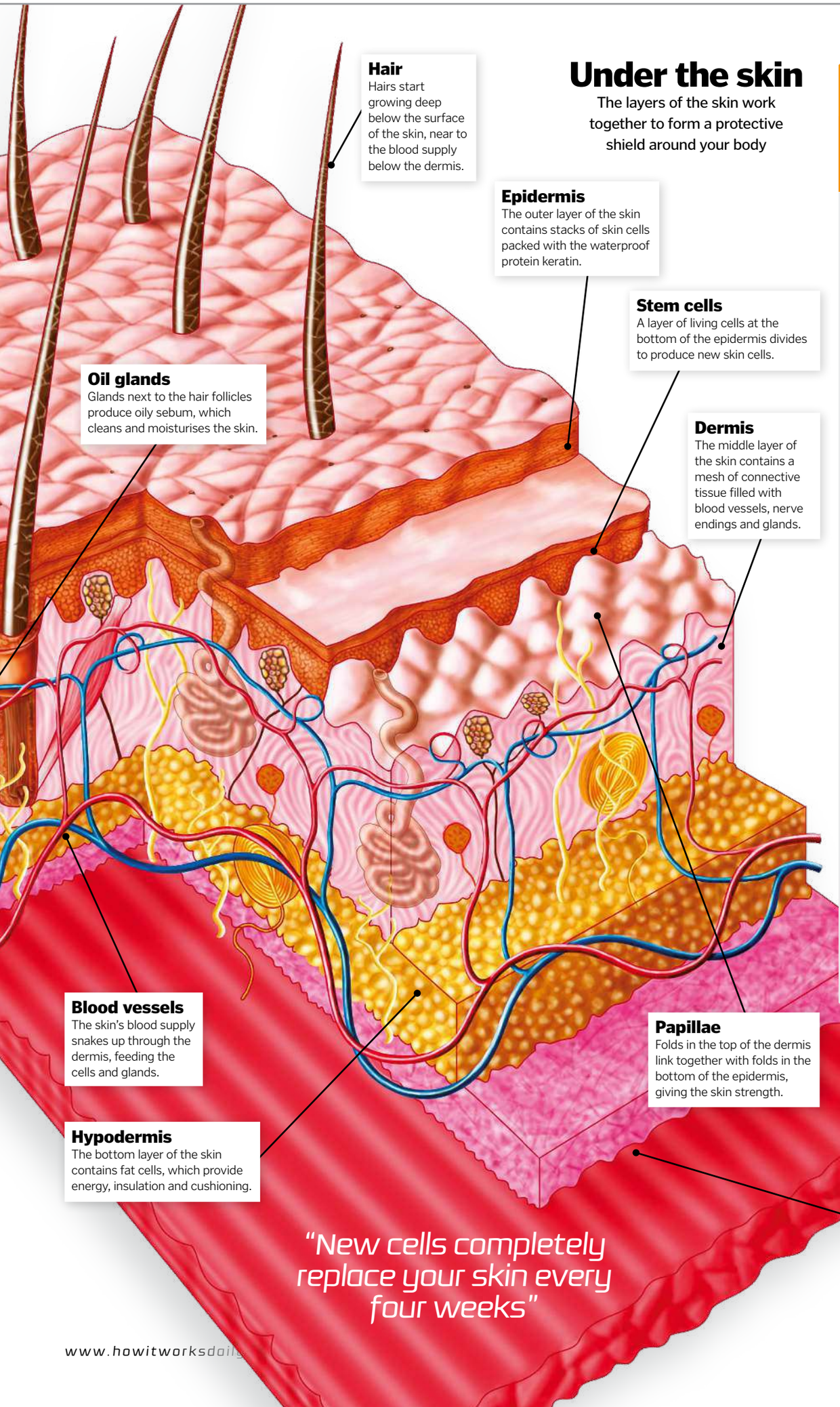
The skin on the palm of your hand has extra layers of cells and fat



Levels of collagen and elastin in the dermis drop as we age

Under the skin

The layers of the skin work together to form a protective shield around your body



Hair
Hairs start growing deep below the surface of the skin, near to the blood supply below the dermis.

Epidermis
The outer layer of the skin contains stacks of skin cells packed with the waterproof protein keratin.

Stem cells
A layer of living cells at the bottom of the epidermis divides to produce new skin cells.

Oil glands
Glands next to the hair follicles produce oily sebum, which cleans and moisturises the skin.

Dermis
The middle layer of the skin contains a mesh of connective tissue filled with blood vessels, nerve endings and glands.

Blood vessels
The skin's blood supply snakes up through the dermis, feeding the cells and glands.

Papillae
Folds in the top of the dermis link together with folds in the bottom of the epidermis, giving the skin strength.

Hypodermis
The bottom layer of the skin contains fat cells, which provide energy, insulation and cushioning.

Muscle
Muscle tissue and fascia (fibrous tissue surrounding muscles) is protected by the fat cells above.

"New cells completely replace your skin every four weeks"

5 FACTS ABOUT WAYS TO CARE FOR YOUR SKIN

1 Use sun protection
Ultraviolet light can seriously harm skin: UVB rays cause sunburn and UVA rays break collagen fibres. Choose sunscreen with a high SPF and a five-star UVA rating to slow the damage.

2 Give up smoking
The chemicals inside cigarette smoke reduce blood flow to the skin and damage the collagen fibres that support your skin cells. If you are a smoker, you can halt early ageing by quitting the habit.

3 Eat colourful foods
Free radicals can harm the skin, but fruits and vegetables contain natural antioxidants, which may help to fight the damage. Maximise your nutrient intake by eating a rainbow of different plants.

4 Wash gently
Harsh soaps and cleansers can strip away your skin's natural oils. Be careful to wash gently and top up with a moisturiser if your skin feels tight or itchy.

5 Look out for sugar
Sugar can grab hold of skin collagen and make the strands more likely to break. A healthy diet and plenty of exercise helps to keep blood sugar under control.

The perfect gift from just £14.99*

PLUS

FREE BOOK

WORTH £10.99

Order hotline 0344 848 2852

Please quote xmas182 when ordering by phone

Lines open Monday-Friday 8am to 7pm and Saturday 10am to 2pm (GMT)

FUTURE myfavouritemagazines
Official Magazine Subscription Store

THE FUTURE OF FASHION

What technology revolutions have made it down the runway and what can we expect to be wearing next?

Words by **Scott Dutfield**

Since 1810 people have worn technology, from the invention of the analogue wristwatch to its digital evolution by 1972. From there began the rise of the 'smart' generation of watches. However, it's not just our wrist wear that's becoming increasingly high-tech, but also the way we produce, measure and create our clothing. From LEDs to built-in sensors, technology's infiltration into fashion is revolutionising the functionality of our clothes.

3D body scanning could become the norm when it comes to finding the perfect fit online. The not-so-distant future could see clothing deliveries disappear, as we'll be able to print our own outfits. Fabrics could be homegrown or even interactive with our smart devices. And our activewear will come with a built-in personal trainer. The possibilities for technological advancements in fashion are abounding. Are we at the beginning of putting fashion into technological overdrive, or will fashionable tech enhance our lives?

A PERFECT FIT

Our sizes differ depending on where we shop, but could 3D scanning end size discrepancies?

One of the main challenges associated with shopping is finding the right size and fit of clothes, and this is something that 3D scanning could help with in future. British tailor Tailor Made and American tailor Alton Lane are just two companies that have adopted 3D scanning in order to produce precisely tailored suits. Sitting inside what seems like a typical changing room at Tailor Made are 3D scanners ready to digitally recreate your body by taking thousands of measurements in just ten seconds. These precise measurements can then be autonomously transformed into actualised patterns to create a suit.

Companies such as ZOZO and StretchSense have gone one further and integrated artificially measuring the human body into a suit itself. ZOZO have created the ZOZOSUIT, a black, skintight suit with white fiducial marker dots. These dots act as reference points for the accompanying app. By taking 12 images using a smartphone, the ZOZO app will create a 3D rendering of your body and analyse the information, similar to a 3D scanner.

StretchSense has applied the same principle. However, they have created a stretch sensor that can be integrated into a smart garment that will measure itself. As the flexible sensors stretch, internal monitors can record the amount of stretch and therefore when incorporated into a suit can calculate the size of the person within it.

Another useful technology in the quest for the perfect fit is laser cutting. Intense beams of light can be used to cleanly slice through fabrics without leaving any stray fibres. This technique can also be used to create garments from a single piece of material rather than stitching together separate sections, which means no more lumpy or irritating seams to contend with!

Measurements
The accompanying software then measures dimensions on the newly created digital model.

The perfect fit
These measurements can then be used by tailors, for example, to create patterns that fit your exact measurements.

Sensors
Once the lasers reflect back off the body's surface they reach sensors that record the distance travelled.

Scanners
Non-harmful laser beams are fired at the surface of the body at various angles to form a digital model of your shape.

Future potential
3D scanning devices for home use could send your details to retailers for ideal fit recommendations.

Three-dimensional tailoring

Discover how 3D scanners are able to take your precise measurements

Personal shopper

Online shopping is quickly becoming standard practice when it comes to retail therapy. Now with developments such as Amazon's Echo Look, it seems stylists are entering the digital space too. By taking a simple snapshot or video of your daily outfit, Echo Look's companion app can curate your closet for future reference. Based on your existing style, the Echo Look will also make online suggestions for future purchases based on your collection. If you're caught between two outfits, Echo Look can also let you know what it thinks looks best. Through learning algorithms and fashion expert advice, Echo Look will compare images of you in your two outfits and produce a comparative percentage for which one it likes best.

The Echo Look can catalogue your looks and suggest some stylish new additions

Laser-cutting technology can produce seam-free garments

PRINTABLE FASHION

Could the future of fashion be just one click away?

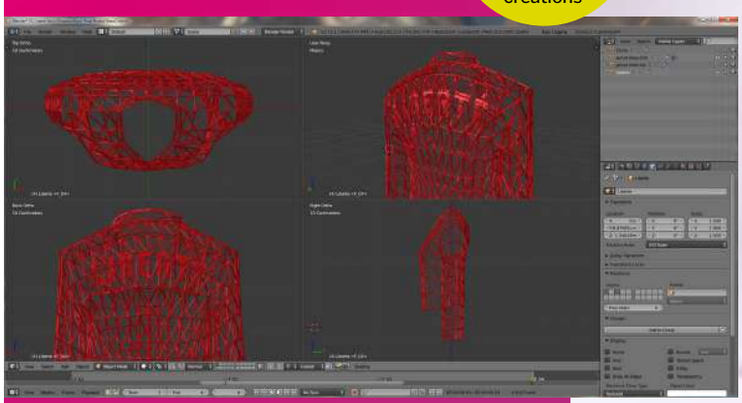
3D-printing has been around for a while, but designers such as Danit Peleg and Julia Daviy are now using it to design their collections. Peleg was one of the first designers to produce a full collection of 3D-printed garments in 2015 and has since produced customisable pieces for purchase online.

During the development and creation of 3D garments the main obstacle to overcome is the filament used to create 3D fabrics. Typically, filaments in 3D printing are rigid plastics such as polylactic acid (PLA), which can be very limiting in terms of recreating a wearable and mobile fabric. However, Peleg utilises the flexible and wearable Filaflex filament to produce garments that resemble lace. A polyurethane-based thermoplastic elastomer, Filaflex is elastic and durable. By combining this with computer-aided design (CAD), intricate patterns and shapes can be created.

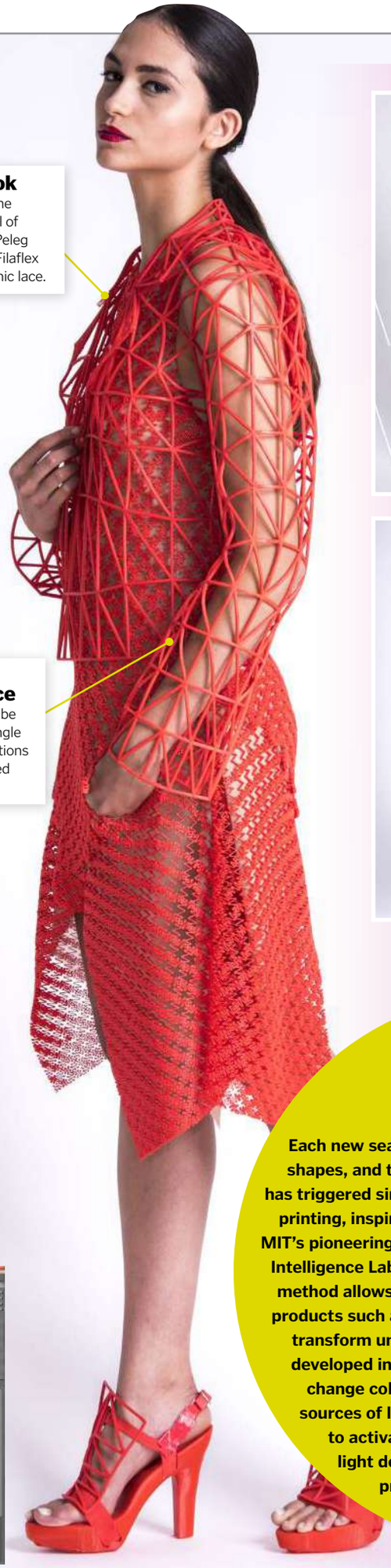
3D printing is still in its infancy when it comes to speed though. Printing a jacket or dress can take hundreds of hours on a domestic-grade 3D printer. Yet this hasn't deterred Julia Daviy, who uses a different method to produce her garments: stereolithography (SLA) printing.

Rather than using a Fused Filament Fabrication (FDM) 3D printer, SLA designs use a UV laser beam to harden a resin layer by layer. The creation rises slowly from the resin, rather than being printed by plastic sections being layered on top of each other.

Both Peleg and Daviy's creations are just some of the many designs that 3D printing is now making possible. The hope is that someday soon customers will be able to download their clothing designs and at the click of a button print them at home.



Computer-aided design software is the starting point for 3D-printed creations



Lacey look
To maintain the moveable feel of fabric, Danit Peleg uses flexible Filaflex plastic to mimic lace.

Printing preference
Garments can be printed as a single piece or in sections to be connected together later.

Colour-changing creations

Each new season brings with it new styles and shapes, and the ever-changing fashion scene has triggered similar change when it comes to 3D printing, inspiring the likes of ColorMod from MIT's pioneering Computer Science and Artificial Intelligence Laboratory (CSAIL). The ColorMod method allows 3D-printed materials used for products such as phone cases and jewellery to transform under ultraviolet light. The MIT-developed ink uses photochromic dyes that change colour when exposed to different sources of light. Ultraviolet light can be used to activate certain colours, while visible light deactivates others, allowing plastic products to change colour to suit the owner.

TRANSFORMATIVE TECH-STYLES

Discover the garments that reveal the possibilities of science between the stitches

Synthetic fabric innovations, or 'tech-styles', are continuously evolving, from printable plastics to graphene dresses. However, one company is taking a traditional material and rewriting its origins. Leather has been a staple in the clothing industry since its infancy and has been used to create a wealth of products, but the fact that it is an animal-based product is inescapable. That's where the biological engineers at Modern Meadow come in, for they have grown a bioleather called Zoa to replace traditional practices in the industry.

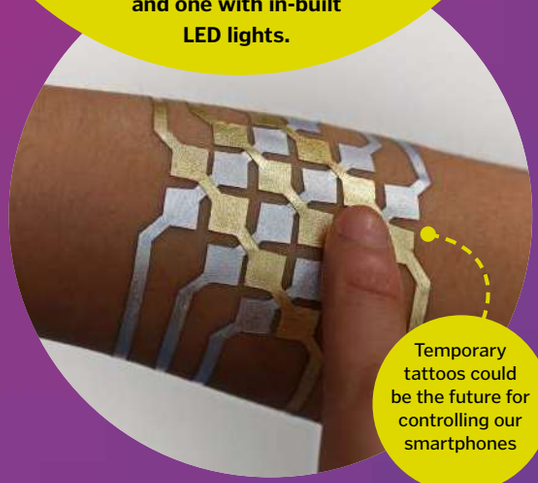
Biofabrication is the ability to grow natural products using cells from a living creature as opposed to the animal itself. By editing animal DNA, Modern Meadow can utilise the cell production of collagen, which can group together to form a network of fibres. These fibres can then be intertwined to form a material structure that can be tanned and finished. The possibility of homegrown materials could revolutionise the way we source our clothes.

Technology in fashion doesn't have to exist as a functional improvement on what we wear. Sometimes wearable technology can be created simply for its aesthetic appeal. Designers at CuteCircuit have taken technology's wearable potential and applied it to couture fashion. One of their most advanced offerings is the graphene dress. In collaboration with the University of Manchester, UK, designers at CuteCircuit have created a couture dress that can capture breathing patterns and displays them through colour-changing LED decoration. Graphene is the strongest material ever produced and the thinnest at an atom thick.

LEDs have been placed on a transparent and highly conductive graphene element and a stretch sensor recorded contractions in the element, displaying the light changes on the surface. A shallow breath results in orange to green light and a deep breath moves the dress from purple to turquoise. This isn't CuteCircuit's only technological venture, with a host of examples in their collections and stand-alone pieces. Back in 2012 they created a Twitter dress, where LED lights embedded in the dress reacted to real-time tweets.

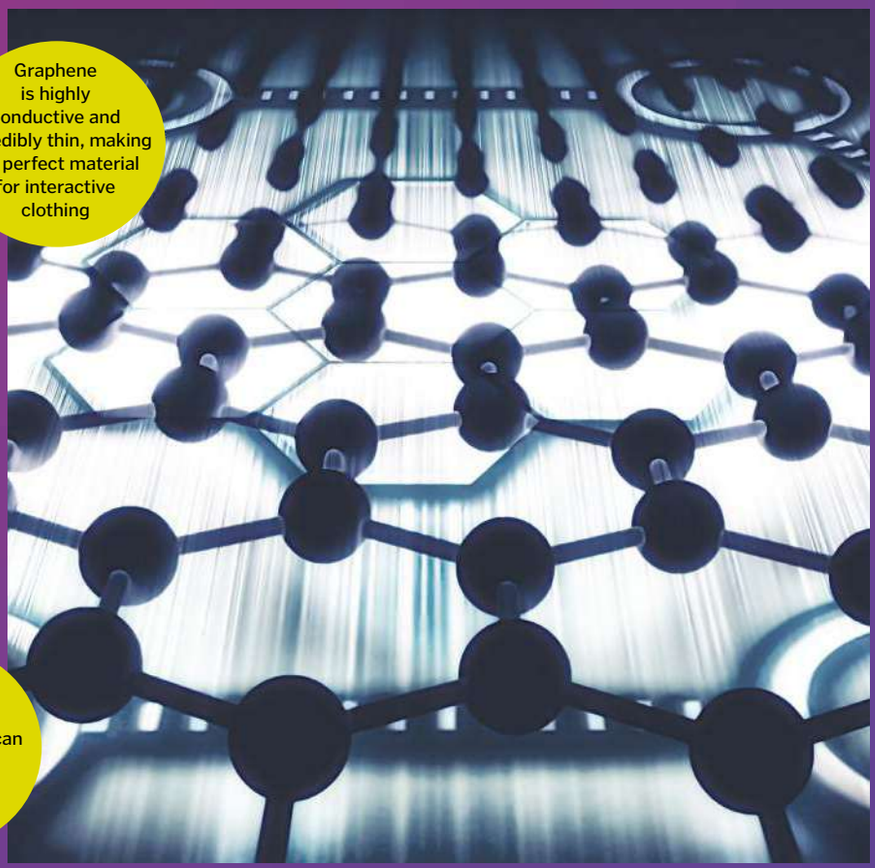
Tattoos of the future

A team from MIT and Microsoft Research have developed metallic temporary tattoos that can act as an interface on your skin. Called DuoSkin, the wearable tech can act as a tracking pad that could, for example, control music volume on a smartphone. The key to the tattoo's ability is the conductive gold leaf material used to form the circuit. Accompanied by tattoo paper silicone, touch electrodes are attached to the gold leaf design and a capacitive touch controller. The information from the tattoo is then transmitted via Near-Far Communication (NFC) to a device. The team also developed a tattoo that changes colour relative to body temperature and one with in-built LED lights.

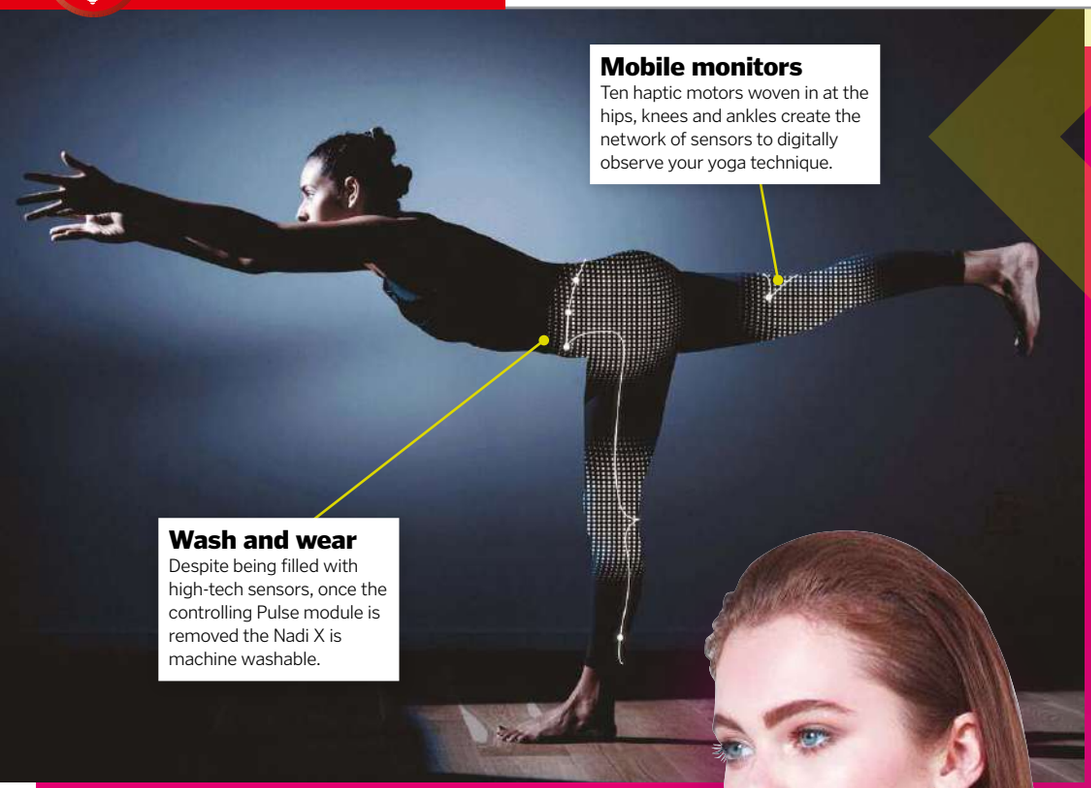


Temporary tattoos could be the future for controlling our smartphones

The first of its kind, the graphene dress can monitor your breathing patterns



Graphene is highly conductive and incredibly thin, making it a perfect material for interactive clothing



Mobile monitors
Ten haptic motors woven in at the hips, knees and ankles create the network of sensors to digitally observe your yoga technique.

Wash and wear
Despite being filled with high-tech sensors, once the controlling Pulse module is removed the Nadi X is machine washable.

SCIENTIFIC SPORTSWEAR

How are designers using the power of technology to optimise our active lifestyles?

Wearable technology is most commonly seen in active wear. Smartwatches and wearable health trackers have become commonplace in the fitness industries to give real-time feedback on aspects such as heart rate, step count and even sleep patterns. There are, however, companies that are taking the demand for more real-time fitness and health information to the next level and integrating devices into fitness fashion.

Companies such as Sensoria Fitness and OMSignal have produced lines of functional clothing to continually monitor cardiovascular activity. With an embedded ECG monitor, garment's can record biometric information such as your heart and respiratory rate. Through Bluetooth connections these garments send the information to an app and AI algorithms process the information to show you real-time results. The algorithms can then offer suggestions during an exercise about your breathing levels and if you've exceeded your optimum heart rate.

Wearable fitness technology doesn't solely have to work as a digital doctor but can also act as a coach, potentially removing the need for instructors, such as those in yoga. Wearable X have created yoga leggings that act as your teacher, guiding you through each pose. The Nadi X are a pair of leggings with technology woven into the fabric. Accelerometers and haptic motors can detect your pose and advise you on the best stance. In order to active the fabric, the Pulse module clips to the leggings and records the information from the built-in monitors. Data from the monitors on the hips, knees and ankles is then sent to the companion app and run through algorithms to assess your yoga success.

Based in Redmond, Washington, US, Sensoria Fitness has developed a range of tech for runners

The Soundshirt

CuteCircuit has not only created couture for its visual appeal but also to enhance the lives of those with a hearing impairment, hence the creation of the Soundshirt. Embedded within the fabric of the shirt are 16 micro-actuators, which receive information from the stage and transcribe that into a real-time sensory experience. Microphones placed around the stage will pick up the different sections of an orchestra, with the sound then converted into data through software before being sent to the shirt's sensors. From the crescendos of the drums felt on the back to the delicate strings of the violins that run down the arm, the sound shirt can encapsulate the wearer within the symphony.

The Soundshirt can allow someone hard of hearing to experience the full force of an orchestra

HIGH-TECH ACCESSORIES

Pair your high-tech fashion with some of these wearable must-haves

Samsung Galaxy Watch

There are a whole host of smartwatches on the market, but one of the newest additions to the scene is the Galaxy Watch. Taking the typical tech of a smartwatch, the Galaxy has a rotating bezel alongside the touch screen function.

Vuzix Blade

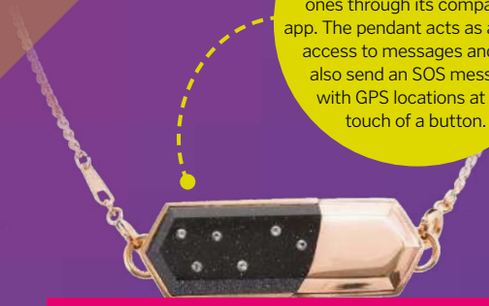
Combining the digital world with the real one, the Vuzix Blade pairs with your phone to display information on its lens, including phone calls, a camera and navigation tools.

Motiv Ring

As a handy Smartphone accessory, Motiv Ring can track your fitness and sleep patterns. Heart rate, calorie burns and step counts are just some measurements that the Motiv can record and display on the smartphone companion app.

Sensoria fitness sock and anklet

These 'smart socks' monitor your running progress and form on a smartphone companion app. Combined with the smart ankle, the app can offer advice on your run and monitor heart rate.



Talsam

This Kickstarter device offers a way to send secret message to loved ones through its companied app. The pendant acts as a key to access to messages and can also send an SOS message with GPS locations at the touch of a button.

Mini-Clutch Speaker™

This compact clutch not only holds your valuables but can also play your favourite songs with its in-built Bluetooth speaker.

HYPERADAPT

Nike have created a pair of trainers that automatically tighten when your foot is placed inside. Through Electric Adaptable Reaction Lacing (EARL), the HYPERADAPT trainers electronically control both pressure and fit for the wearer.

Disney's Stuntronics

Death-defying stunts are a breeze for these advanced acrobatic robots

The latest version of Stickman can perform complicated aerial stunts

The field of robotics has played a major role in many movies through the years. From animatronic sharks to mechanical monsters from far off worlds, robots have often been in the spotlight, particularly before CGI technology was widely adopted. Earlier this year, however, Disney released details of their new acro-bot, Stickman, showcasing robots' aptitude for stunt work as part of their 'Stuntronics' project.

Capable of performing mid-air flips and tumbles, Disney's Stickman somersaults through the air and sticks a perfect landing every time. It is just over two metres tall, similar in shape to an acrobat with their arms stretched out above their head and swings from a gravity-driven pendulum.

To begin the somersault, the Stickman is attached to the pendulum by a cable. As the pendulum swings, the robot will swing with it and at the perfect height will release from the cable, tuck, rotate, untuck and land. As it glides through the air its motion is reminiscent of a gymnast somersaulting from the high bar.

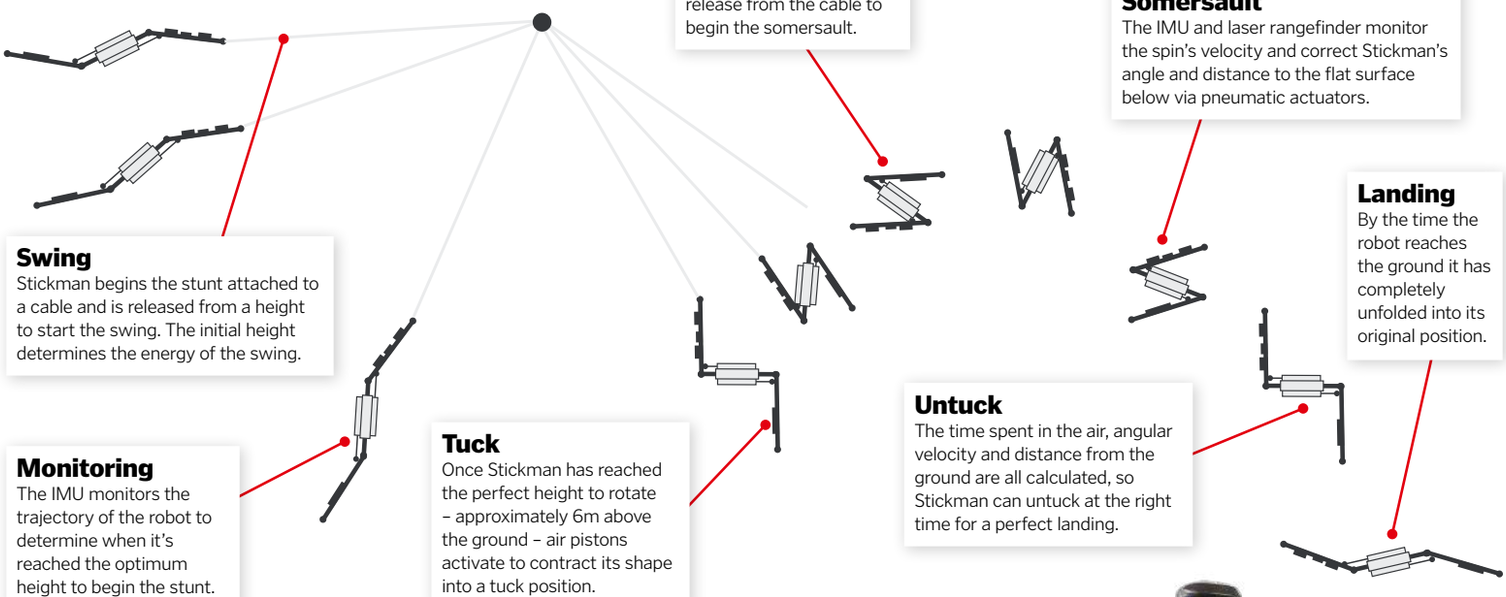
Stickman uses air tank stores to contract and extend its shape to achieve the somersault rotation. But it's the built-in Inertial Measurement Unit (IMU) that monitors and makes critical calculations of the robot's positions during movement to create the perfect flip. Together with laser rangefinders the robot can calculate its position and change its motion from flip to floor.

Since unveiling the relatively simple Stickman, Disney have released footage of their latest version, a 40-kilogram humanoid stunt figure that can make its own movement decisions in real-time. This more realistic robot performs a range of flips and can soar through the sky like a superhero from the movies.

Disney Research are responsible for building the physical BB-8 used in *Star Wars Episode VII* and *VIII*

Scientific somersault

How does the acro-bot know how and when to flip?



Swing
Stickman begins the stunt attached to a cable and is released from a height to start the swing. The initial height determines the energy of the swing.

Monitoring
The IMU monitors the trajectory of the robot to determine when it's reached the optimum height to begin the stunt.

Tuck
Once Stickman has reached the perfect height to rotate – approximately 6m above the ground – air pistons activate to contract its shape into a tuck position.

Release
Once in the tucked 'Z' configuration the robot will release from the cable to begin the somersault.

Somersault
The IMU and laser rangefinder monitor the spin's velocity and correct Stickman's angle and distance to the flat surface below via pneumatic actuators.

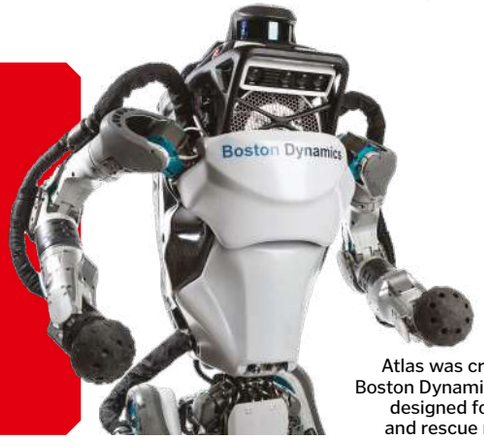
Untuck
The time spent in the air, angular velocity and distance from the ground are all calculated, so Stickman can untuck at the right time for a perfect landing.

Landing
By the time the robot reaches the ground it has completely unfolded into its original position.

Dynamic duo

The creation by Disney's research division is not the only robot capable of somersaulting on its own. One of the leading developers in robotics is Boston Dynamics, and they have created a robot that can perform a perfect backflip.

Atlas is a humanoid robot that can coordinate its limbs and torso to replicate human motion. It uses lidar and stereo camera vision as its eyes to see the world. Lidar is a detection system to map out Atlas' surroundings, much like radar but using light. This 'light radar' measures the time taken for a small beam of light to hit the ground or surroundings and return to Atlas. This time can then be converted into distance, creating the perfect picture of the world around it.



Atlas was created by Boston Dynamics and is designed for search and rescue missions

Welbeck

The Defence Sixth Form College

WELBECK DEFENCE 6TH FORM COLLEGE

The A level Pathway to **STEM** Careers in Defence

For potential engineers with drive, ambition and ability, Welbeck is where potential turns into bright futures as officers in the British armed forces or civilian engineers with the civil service.

- Students attain a minimum of three STEM A levels at Welbeck including Maths
- Welbeck tuition funded by the Ministry of Defence with means-tested boarding fees
- Choice of over 200 degree courses at 11 Partner Universities
- Students receive £4000 per year bursary whilst at university
- Starting training salary of circa £25,000 rising to £30,000 on completion of service training

Eligibility criteria apply. Please visit **www.dsfc.ac.uk** for more information, to order or download a prospectus and book a place on one of our Open Days.

london transport museum

ENGINEERING
TAKE A CLOSER LOOK

INGENIOUS ENGINEERING

Discover new galleries and exhibitions at London Transport Museum

KIDS GO FREE

- **FUTURE ENGINEERS** – play with new tech and experience driving an Elizabeth Line train in a recreated train cab
- **DIGGING DEEPER** – explore 150 years of Tube tunnelling
- **THE SECRET LIFE OF A MEGAPROJECT** – uncover lesser known stories about the Crossrail project

Adult tickets allow unlimited daytime entry

MAYOR OF LONDON

ltmuseum.co.uk
Registered charity number 1123122

Year of Engineering partners

Bombardier Transportation • DCMS/Wolfson Museums and Galleries Improvement Fund • Biffa Award and Association of Independent Museums (AIM) • Luke Rees-Pulley Charitable Trust • Cubic Transportation Systems • Jacobs • Mastercard • Microsoft • Mott MacDonald • London Transport Museum Friends

Inside the new Apple Watch

We take a look under the glass of the thinner, more powerful Apple Watch Series 4

It's autumn, and that means three things. Your flip-flops are being replaced by warm socks. The leaves are starting to turn brown. And Apple has just released some new technology.

This year we have an all-new Apple Watch, featuring a larger screen, a thinner design and some smart new health features that are sure to help save lives. When it's on someone's wrist, it looks so similar to the previous Apple Watches that you may not even give it a second look. But underneath all that glass is some impressive new tech.

First, it's got a faster, more efficient chip, which has meant Apple could make it slimmer without reducing the battery life. On the back of the watch you'll find the optical heart-rate sensor that was in previous models, along with a new electrical ring. Paired with the metal in the digital crown (the dial on the side of the watch), this forms a simple electrocardiogram, or ECG machine. It can record your heart beat and tell you whether you have cardiac problems, so you can send the report to your doctor. That's really smart – although unfortunately the feature is only approved for use in the US so far, with global roll-outs still a way off.

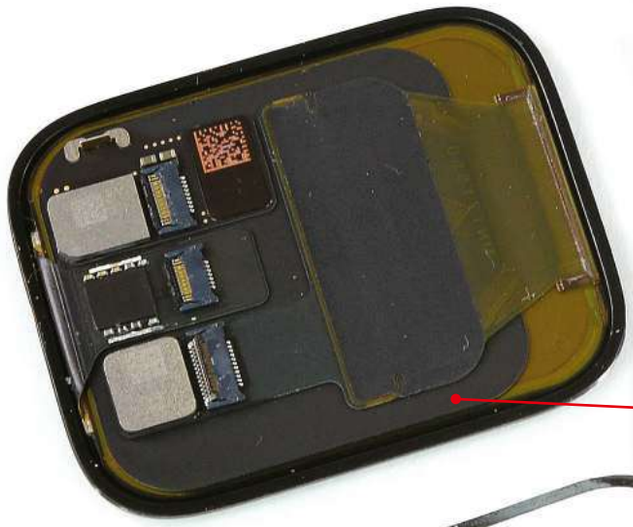
On the front of the watch you'll find a new, 30 per cent larger display. It's thinner and extends right to the edge of the watch, curving at the corners. Just like before, it's waterproof down to depths of 50 metres and tracks workouts, activity and more.

But enough about its impressive abilities. Let's take a look inside at the tech that makes all this possible.

The Walkie-Talkie app lets you speak to your Watch-owning friends by pressing and holding the button, then waiting for a response. It's great fun!

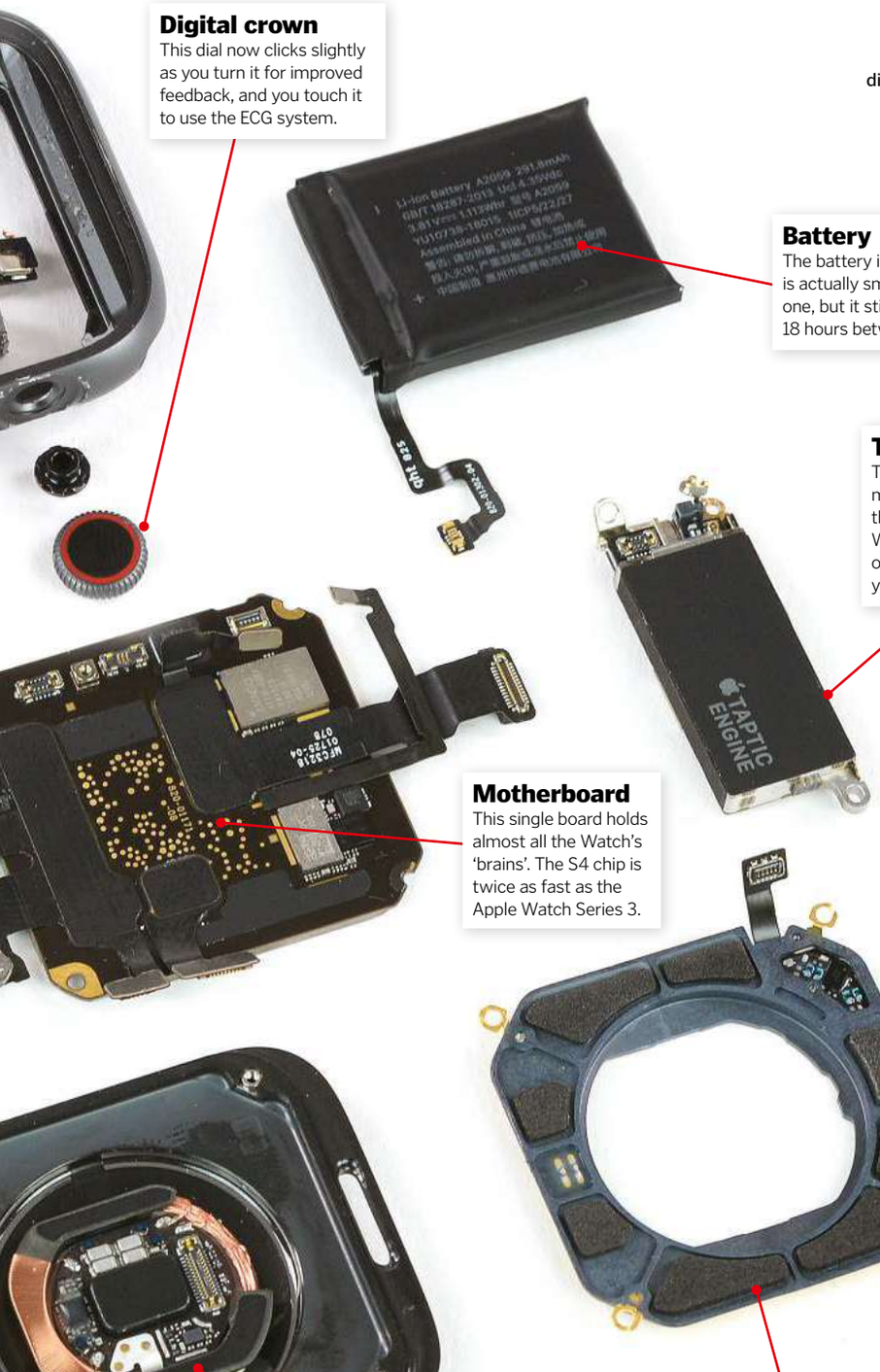
Speak up
This larger speaker is 50 per cent louder than the previous model and uses a silicone gasket to keep the water out.

Casing
The casing has been redesigned to be thinner and more accessible, so your new Watch is easier to repair if it breaks.



Display
This OLED display extends close to the edge of the glass, and the deep blacks blend right into the background.

What's inside the new Apple Watch?
Let's find out how the tech giant's latest smart timepiece works



Digital crown
This dial now clicks slightly as you turn it for improved feedback, and you touch it to use the ECG system.

Battery
The battery in the new Watch is actually smaller than the old one, but it still manages around 18 hours between charges.

Taptic engine
This little box uses magnets to create the feeling that the Watch is tapping you on your wrist when you get a notification.

Motherboard
This single board holds almost all the Watch's 'brains'. The S4 chip is twice as fast as the Apple Watch Series 3.

Padding
This plate sits inside the back case and absorbs heat from the motherboard to stop it reaching your wrist.

Heart sensors
The back panel contains the wireless charging ring, as well as the electric ring that touches your wrist to enable ECG measurements.

The new screen is bigger, which has allowed Apple to display a huge amount of useful information on the watch face

Healthy living

As well as encouraging you to stand regularly and be more active, the new Apple Watch has some smart features that can keep your body healthy in other ways too. The ECG measures using electrodes built into the digital crown and the back crystal on your wrist, and it can classify if the heart is beating in the normal pattern, or if there are signs of atrial fibrillation – a heart condition that causes irregular, often abnormally fast heart rates.

The Watch will also know if you've taken a hard, unexpected fall by analysing your wrist's trajectory. If you don't respond within 60 seconds of the fall notification, the Watch will automatically call the emergency services so they can get to you and help. If there's ever been a watch that's more concerned about your health, we haven't seen it.

"It's got smart new health features that are sure to help save lives"

INSIDE T

P

THE RED PLANET

NASA's InSight lander will tell us more about the interior of Mars than ever before

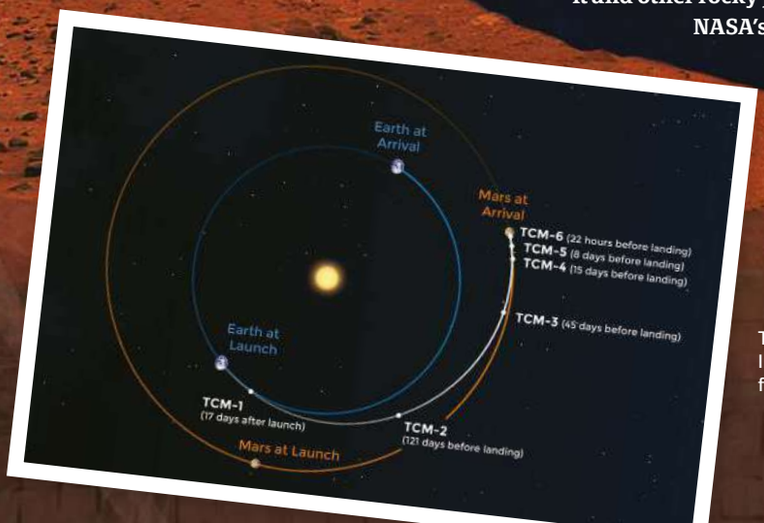
Words by **Jonathan O'Callaghan**

Over the last five decades we have sent a host of missions to Mars. Some have been orbiters, designed to image the planet from afar. Others were rovers sent to probe the surface and analyse rocks at different locations. But now a new mission will do something we've never done before – it will try and peer inside Mars itself, telling us not only what the planet is made of, but how it and other rocky planets formed.

> *"InSight will try and peer inside Mars itself"*

NASA's InSight mission was launched on 5 May 2018 from the Vandenberg Air Force Base in California on an Atlas V rocket. After a journey of about 485 million kilometres, it is scheduled to touch down on Mars on 26 November 2018. Mars is hard, and many missions have failed, so there's always a chance InSight won't make it. But presuming it does, these next few pages will run through what this pioneering mission will do on Mars for just over one Mars year (two Earth years).

InSight is a stationary lander, like NASA's Phoenix lander on Mars in 2008, which means it won't be roving around the surface. Instead, it will touch down in a location near the equator called Elysium Planitia, where it will stay for the entirety of its mission. This region was picked for a number of reasons, one being that it is relatively smooth, thereby minimising any problems when landing and providing an easy environment in which to conduct science. It also has an abundance of sunlight, meaning InSight's solar panels will



This map depicts InSight's trajectory from Earth to Mars

receive plenty of juice. The landing site is also important for the actual landing itself, giving the spacecraft enough atmosphere to slow itself down.

To touch down on Mars, other spacecraft have relied on airbags or a sky crane system with thrusters, as in the case of the Curiosity rover in 2012, to land on the surface. InSight is a little bit different. First, about seven minutes before it enters the atmosphere it will jettison the cruise engine that has taken it to Mars. It will enter the atmosphere at about 21,240 kilometres per hour, with a heat shield taking the brunt of the entry. Temperatures are expected to reach about 1,500 degrees Celsius.

Roughly three and half minutes after entering the atmosphere InSight will deploy its parachute 12 kilometres above the surface, travelling at 1,500 kilometres per hour. The spacecraft will descend with its parachute for about three minutes, using its radar to sense the distance to the ground and extending its three legs. Then, 1.2 kilometres above the surface, it will use 12 descent engines to slow itself down, bringing it to a relatively gentle touchdown at 8.7 kilometres per hour.

> "Once on the surface, the real fun begins"

Once on the surface, the real fun begins. The lander will get to work immediately, unfurling its ten-sided solar panels to create a collection area the size of a ping-pong table. On top of the lander are its various instruments and pieces of equipment, a smorgasbord that a robotic arm with a mechanical hand will be able to grab and place on the surface. Before it does this, though, it will use two onboard cameras to image the surrounding area and pick the best place to deploy its instruments.

These instruments are designed to study Mars in a whole new way. Previous missions have focused on the surface, but InSight will be looking underground. Of particular interest is trying to work out what is actually inside Mars and how similar its interior is to Earth. While both planets are rocky, Mars is now a relatively dead and dusty world. Under its surface could be a whole different matter, however, so a seismometer experiment called the Seismic Experiment for Interior Structure (SEIS) will be placed on the surface to try and listen to seismic waves travelling throughout Mars. These are produced by so-called 'marsquakes' in a number of ways, one being meteorites hitting the surface, another being the planet cooling and contracting, and another being magma rising up from its suspected molten core.

By monitoring these waves and measuring their speed, frequency and size, the seismometer will be able to work out what material is inside Mars. We don't actually know if the core of Mars is solid or liquid, something this experiment could reveal. We also don't know how thick its next two layers are, the mantle and crust, the former likely rich in silicon and the latter made of less-dense rocky material. Studying exactly what Mars is made of, and how its structured, could not only tell us about the Red Planet itself but others too.

Our Solar System has four rocky planets, but we're starting to find bucket-loads elsewhere in the galaxy. In our Solar System though, only one – Earth – became the habitable, pleasant world it is today. Understanding the formation and structure of Mars could help tell us why Mars is not the

A large parachute will help InSight land on the Martian surface

InSight's equipment

How this lander will study the surface of Mars like never before

Solar arrays
Two ten-sided solar arrays, each 2.15m across, will deploy on the surface to provide power to the lander.

Shield
A wind and thermal shield will be placed over SEIS so its measurements aren't interrupted.

SEIS instrument
The Seismic Experiment for Interior Structure (SEIS) will take the 'pulse' of Mars. Shaped like a dome, the instrument will measure the seismic vibrations of the planet caused by meteorite impacts and 'marsquakes'. It'll also measure vibrations caused by Martian weather, and it could even find liquid water underground.

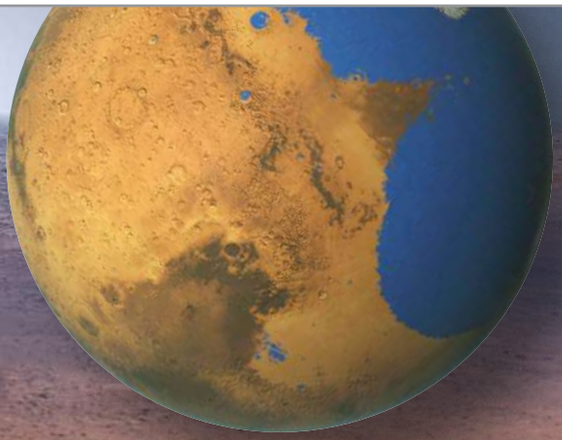
Pendulums
The motion of three pendulums inside the SEIS instrument will be measured electronically to detect vibrations.

Ground
The SEIS instrument will be placed onto the surface by the arm onboard InSight.

Instrument Deployment Camera
The Instrument Deployment Camera (IDC) will take colour images to pick locations to deploy the instruments.

Instrument Deployment Arm
This 2.4m-long arm will remove instruments from the lander and place them on the ground.

Grapple
This 'hand' at the end of the arm has five mechanical fingers that will grab instruments from the lander.



One-fifth of Mars may once have been covered in water until it lost its magnetic field

Ultrahigh Frequency (UHF) antenna
The lander's UHF antenna will send data to orbiting Mars spacecraft to be relayed to Earth.

RISE antenna
The Rotation and Interior Structure Experiment (RISE) will measure the wobble of the planet, specifically the north pole, where InSight will be landing. This will help us work out if the core is liquid and what it's made of, telling us how similar Mars is to Earth inside.

Instrument Context Camera
The Instrument Context Camera (ICC) has a fisheye lens that will take wide images of the lander and its surroundings.

HP³ instrument
The Heat Flow and Physical Properties Probe (HP³) will measure the temperature of Mars. It will do this by hammering a sensor as far as 5m underground. This will measure how much heat is coming from the interior of Mars, telling us what's going on inside the Red Planet.

The launch took place in rather foggy conditions on 5 May 2018

The launch

InSight was launched from Vandenberg Air Force Base on the central coast of California on 5 May 2018. That choice of launch site was somewhat unusual, as missions to other planets usually lift off from NASA's Kennedy Space Center in Florida. From the latter, rockets can launch east over the sea, getting an additional boost to their momentum from Earth's rotation. However, InSight was launched on the powerful Atlas V-401 rocket, which was strong enough that it could launch the spacecraft south from Vandenberg over water.

same, although we do think it once had water on its surface just like Earth. Learning how Mars formed differently to Earth will be crucial in understanding the broader picture of what ingredients a rocky planet needs to become habitable.

Helping in this endeavour will be another instrument deployed by InSight called the Heat Flow and Physical Properties Package (HP^3), developed by the German Aerospace Center (DLR). This is essentially a probe that will be hammered into the surface of Mars up to a depth of five metres, deeper than any instrument on Mars before. A motor will create tension in a spring, which will drive a hammer down a cylindrical shaft into a spike at the bottom called the 'mole', requiring between 5,000 and 20,000 hits over 30 to 40 days depending on how compact the soil is. This will gradually burrow into the ground, and once it reaches its maximum depth, 14 sensors up the tether will begin to measure the temperature at different depths.

> *"InSight is a groundbreaking mission"*

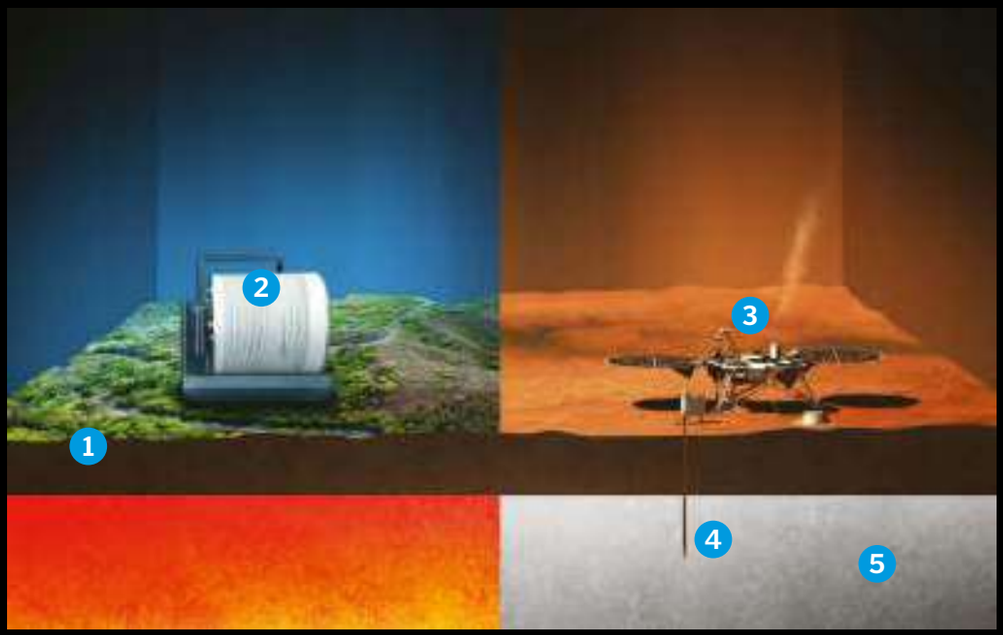
Why? Well, the goal of HP^3 is to work out how much heat is flowing out of the interior of Mars and the rate it is doing so as it travels up the sensors. Heat flow is deemed to be a planet's 'vital sign', with heat being crucial to shaping the geology of a planet, from its canyons to its mountains. It can also play a role in delivering water to the surface, and we think there might be some water hiding under the surface of Mars. What's more, if the energy of Mars' core is diminishing – which it might be, as the planet mysteriously lost its magnetic field billions of years ago, one likely powered by an active core – then this instrument could tell us how long Mars has left before it truly dies.

The last main science goal aboard InSight is the Rotation and Interior Structure Experiment (RISE). Unlike the other two experiments, however, this does not have its own dedicated equipment. Instead, it will be using the direct radio connection InSight has with Earth to measure how much Mars is wobbling as it rotates. Amazingly, InSight will use its antennae to measure its location in space to a precision of less than ten centimetres. This will tell us how much the rotation axis of Mars is swaying.

This is important because it will tell us how big the core of Mars is. Previous findings have suggested the core is extremely dense and

Seismic activity

How we can measure seismic activity on Mars compared to Earth



1 Rocks
When rocks move or break apart we can measure the seismic waves they produce as they bounce around the planet.

2 Seismometer
A seismometer is specifically designed to measure the size, frequency and speed of seismic waves, also called quakes.

3 Location
On Earth we take measurements from multiple locations, but InSight will have to do it from just one.

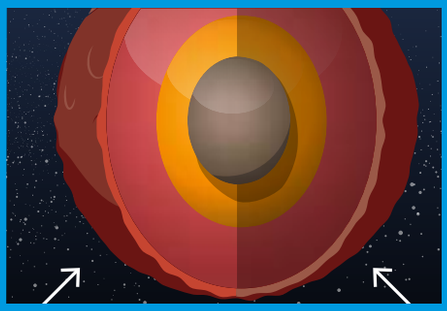
4 Number
InSight is expected to detect up to several hundred seismic waves, as well as quakes produced by meteorite impacts.

5 Material
Detecting the characteristics of the wave can tell us what material it has passed through – a glimpse at Mars' interior.

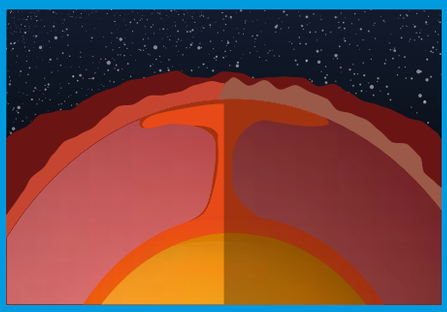
InSight could tell us more about rocky planets in our Solar System and beyond

Marsquakes

Mars doesn't have plate tectonics like Earth, so how does it have quakes?



Contraction
One method thought to produce marsquakes is the cooling and contraction of the planet, creating detectable seismic waves.

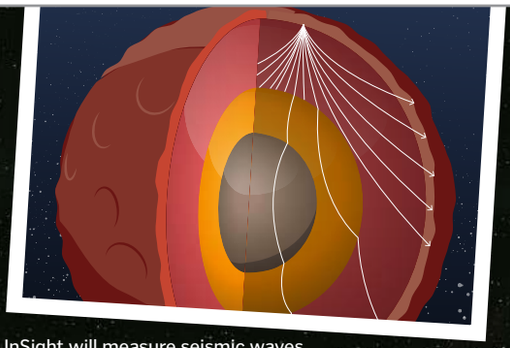


Magma
Magma coming up from the core of Mars could also be responsible for producing marsquakes and seismic waves.

Impacts
Meteorites hitting the planet could cause tremors that the super-sensitive seismometer on the SEIS instrument will pick up.

possibly partly molten, but to find out its exact size we need to monitor it for a long time. Rovers and orbiters aren't very good at doing this as they keep moving around, but InSight will be staying in one location. It's hoped this could tell us a huge amount about the core of Mars and, in turn, tell us more about the innards of rocky planets in general.

There's little doubt that InSight is, in every sense of the word, a groundbreaking mission. It will literally hammer into the ground, while simultaneously listening to the pulse of the planet and the wobble in its spin. The primary mission of the lander is expected to end on 24 November 2020, and by then we might have a whole different outlook on just how special Earth is in the universe compared to other rocky planets. Perhaps Mars was once more like us than we thought – or perhaps our planet really is one of a kind.



InSight will measure seismic waves travelling through the surface of Mars

Rocky planet formation

How we think terrestrial planets form and what InSight could add

Pebble
Our leading theory is the 'pebble method', that small rocks gradually join together (accrete) over time under gravity.

Birth
As the protoplanet grows in size it scoops up more and more pebbles from the surrounding space.

Layers
The planet is now separated into layers, with a hard crust above the mantle and the core in the middle.

Melt
Elements inside the planet start to heat up and melt as the planet begins to form.

Heat
The pressure at its core increases as the planet grows, as does its temperature.

Core
The lighter elements float towards the surface of the planet, while the heavier elements sink to the core.

InSight
By studying Mars' innards, InSight will try to see signs of how this planet took shape.

Measuring a galaxy's mass

How we work out the weight of galaxies in the universe

The idea of weighing a galaxy might seem a bit weird – it's not like we can put it on a giant cosmic set of scales. But by using some clever observations and tricky equations, it is indeed possible to work out the masses of other galaxies in the universe.

There are actually a number of ways to do it, but one popular method is to look at the orbital motion of stars in a galaxy. Those in a more massive galaxy will move faster than those in a less massive one, so measuring their speed can help scientists work out the answer. Scientists also look at the overall rotation rate of galaxies to work out their mass. They do this by measuring the redshift or blueshift – the amount that a particular side of a galaxy is moving away from or towards us respectively – and seeing how much the light shifts to each end of the spectrum. Another method involves looking at the gravitational pull exerted on star clusters in space by nearby galaxies. The bigger the pull, the more massive the galaxy, and we can use this to estimate just how heavy it really is.

Yet another method involves gravitational lensing, which is the lensing effect caused when a galaxy passes in front of a distant object in our line of sight. Depending on the gravitational strength (and therefore mass) of the lensing galaxy, this can produce either a large or small lensing effect, something that was predicted by Einstein and that is known as an Einstein ring. However, these events are rare in the universe, so the chances of us measuring a galaxy in this way are slim.

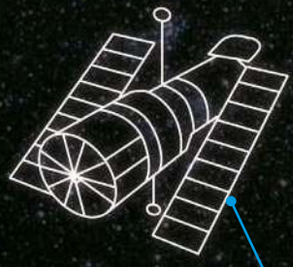
Above: Scientists estimate that there are 2 trillion galaxies of varying masses in the known universe!

Left: An Einstein ring can help us measure the mass of a lensing galaxy

Two measuring methods

Here are two ways used to estimate the mass of galaxy ESO 325-G004

Very Large Telescope
A telescope on Earth, in this case the Very Large Telescope (VLT), is used to observe the galaxy.



Hubble Space Telescope
Alternatively, a telescope like Hubble can be used to get a different measurement of the mass.

The Milky Way

We can measure the mass of other galaxies, but how do we measure our own when we can't see the big picture from afar? The best way to do it is to measure the speed and motion of stars in our galaxy, although to get an accurate reading you need to measure at least 100,000 stars, and maybe millions to be sure.

Another way to get a good estimate is to look at 'tracers' behind our galaxy. These are rogue stars and galaxy fragments that now trail behind us, and their velocity and angular momentum can tell us how much they have been pulled by our galaxy, thus indicating its mass. The most recent estimate suggests our galaxy is about 960 billion times the mass of our Sun.

As we're inside the Milky Way it can be tricky to measure its mass

"The bigger the pull, the more massive the galaxy"

Stars
Scientists measure how fast the stars are moving to see how much mass there is in the galaxy.

Distance
Even though it's over 450 million lightyears from Earth, we can still work out the galaxy's mass.

Einstein ring
Measuring the strength of the lens tells us the galaxy's gravitational strength, so we can estimate how much mass it has.

Gravitational lens
This galaxy was found to be a gravitational lens, bending the light of a much more distant galaxy with its gravity.

Hidden mass

One issue with measuring the mass of galaxies is the galaxy rotation curve problem. When an ice skater pulls in their arms during a spin, you would expect them to move faster as their mass is more concentrated towards their centre. So in a galaxy, you'd also expect the stars nearer the centre to move faster, but that's not the case. Instead we find that stars towards the edge of a rotating galaxy actually move faster, not slower. Scientists think the answer is the presence of invisible dark matter. The gravitational tug of dark matter causes the stars at the edge to move faster than theory predicts and thereby helps iron out any discrepancies in the measurement of a galaxy's gravity and mass.

Dark matter is thought to affect the rotation rate of galaxies

SATISFY YOUR HUNGER FOR KNOWLEDGE WITHIN THE PAGES OF THIS BOOK!

Find out everything that you need to know about stimulating science, trailblazing transport, transformative technology, spectacular space, humorous history and the extraordinary environment!

ON SALE NOW

FUTURE

Ordering is easy. Go online at:

www.myfavouritemagazines.co.uk

Or get it from selected supermarkets & newsagents

The make-up of the Moon

The Moon's violent history has led to its rather colourful present

A future lunar base will look to utilise the valuable resources at the poles

KEY

- Volcanic lava flows
- Highlands; low in titanium and iron
- Mare Tranquillitatis; rich in titanium
- Recent impacts; thin, mineral-rich soil

Regardless of what Wallace and Gromit may have told their viewers, the Moon is not made of cheese. The fifth largest moon in the Solar System, and our nearest neighbour, is made primarily of rock. Almost similar to Earth, the Moon is also composed of a core, mantle and crust, but its geological activity is extinct now.

The centre of the Moon is an iron-rich core accounting for roughly 20 per cent of its radius. There is a partially molten region surrounding the iron core and then a mantle that stretches between the molten core layer to the crust of the Moon, most likely composed of minerals like olivine and pyroxene.

The crust of the Moon has a thickness ranging from 70 to 150 kilometres, and its composition has been observed to contain oxygen, silicon, magnesium, iron, calcium and aluminium. It also contains relatively small amounts of titanium, uranium, thorium, potassium and hydrogen. All of these elements make up the stunning surface of the Moon that everyone can see from Earth, consisting of dark Maria (Latin for 'seas') that were once impact basins filled with lava. The volcanoes spread all over the lunar surface were once active, but now they all lie dormant, having not had an eruption for millions of years. The only refreshment the surface receives is when an asteroid hits it, causing the many impact craters visible from Earth.

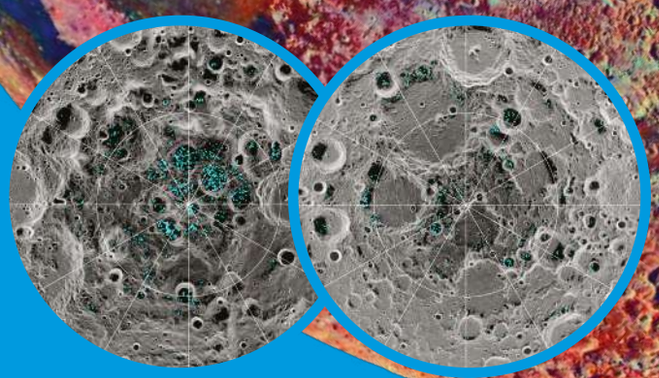
NASA's Galileo spacecraft imaged the Moon's northern hemisphere using its Solid-State Imaging (SSI) instrument while on its voyage to Jupiter, creating a spectacular image. The SSI was capable of capturing many different images in varying wavelengths ranging from visible to near-infrared light. The different wavelengths correspond to a different colour and composition, meaning the scientists behind the mission could visually distinguish the different compositions on the lunar surface.

Water ice found at lunar poles

From data collected by the Indian Space Research Organisation's Chandrayaan-1 spacecraft, launched in 2008, scientists have found definitive evidence of water ice located at both poles of the Moon.

Courtesy of NASA's Moon Mineralogy Mapper (M3) instrument, scientists were able to detect the presence of solid ice. The instrument was able to locate the reflective properties expected from ice and also differentiate between liquid water or vapour and solid ice based on the distinctive way its molecules absorb infrared light.

These sources are located in the shadows of craters near the poles, where temperatures never get above -157 degrees Celsius. This has tantalising implications for any mission back to the Moon, as the water could possibly be used as drinking water or even rocket fuel for future exploration.



The blue spots represent the ice observed at the Moon's south (left) and north (right) poles


B3889
ZX

EVOLUTION OF THE RAF

On 1 April 2018, the world's first independent air force celebrated 100 years since its formation

Words by **Tim Williamson**

For over a century the Royal Air Force has played a key role in all the major conflicts of the world, from the heroic pilots of the Battle of Britain to the fast-jet strikes of the first Gulf War. The service is almost as old as flight itself, and during its history it has remained on the cusp of the latest aviation technology, adapting to the huge shifts in tactics along the way and pushing the limits of human possibilities in the sky.

WWI ORIGINS

When the RAF was officially founded in 1918, it reformed and simplified the existing chaotic system, uniting the separate branches of the Royal Flying Corps (controlled by the Army) and the Royal Naval Air Service (controlled by the Navy). Because these two services were entirely separate entities they had struggled to co-ordinate and co-operate with regards to the design and production of aircraft, or even an effective strategy for home defence.

In 1917, Jan Smuts, a member of the British War Cabinet, proposed the radical change in the organisation and command of Britain's air fleet, creating an entirely new branch of the military that would operate with its own independent hierarchy. The commissioning of aircraft models would be drawn from a single budget, meaning greater consistency and effectiveness of the designs. This new service would also bypass the rivalry between officials in the Navy and the Army, who competed for priority over resources.

Despite this sweeping re-organisation, for the pilots on the frontline the birth of the RAF had very little immediate effect. By 1918, airmen on both sides of no man's land had developed highly effective methods for reconnaissance as well as fighter interception. The war's vicious aerial dogfights had evolved from clumsy encounters in 1914 to fast-paced, even acrobatic dances of death. Aerial photography was already being used to great effect in reconnaissance patrols and directing artillery fire, and pilots were also regularly co-ordinating with ground forces in devastating combined arms offensives.

Just over two weeks after the formation of the RAF, the most famous and successful pilot ace of the war was finally shot down. Manfred von Richthofen, known as the 'Red Baron', was killed while pursuing Lieutenant Wilfrid May of 209 Squadron. Although the fatal shot was thought to have come from ground fire, the squadron nonetheless adopted a falling red eagle as its crest in honour of their vanquished foe.

For the last seven months of WWI the air force would be integral to the final campaigns on the Western Front. At the time of the Armistice in

The RAF's newly acquired F-35 Lightning stealth fighters were a highlights of the 2018 flypast celebrations

November 1918 it was one of the foremost air powers in the world, with over 293,500 personnel of all ranks and some 22,000 planes.

THE FINEST HOUR OF 'THE FEW'

The inter-war years (1919–39) saw the RAF greatly reduced in strength – by 1922 it held only around 40 aircraft in service. Nonetheless, new technology and tactics continued to develop as Britain exerted its control across its empire. The first independent RAF campaign took place in 1925 in Waziristan (a region in Pakistan). Significantly, this was also the first independent bombing campaign of the air force, foreshadowing a brutal new strategy.

In 1936 the RAF reorganised into separate Commands – Fighter, Bomber, Coastal and Training – in order to more effectively co-ordinate the vastly different operations requirements, such as defensive interception and offensive bombing missions. This structure would prove crucial in the coming conflict.

In another vital development that same year, the Spitfire made its debut flight from Eastleigh Aerodrome, Hampshire, displaying its incredible speed and agility in the air. Before long it would be put to the test in real combat.

Although war with Nazi Germany began in September 1939, it would be several months before the RAF could make its first significant impact. During the evacuation of over 300,000 French and British soldiers from Dunkirk in May–June 1940, Fighter Command provided vital air cover. Although outnumbered, RAF squadrons prevented the Luftwaffe from gaining air superiority over Dunkirk, which would have been catastrophic for the stranded armies. Praising this effort, Winston Churchill later asked, "May it not also be that the cause of civilisation itself will be defended by the skill and devotion of a few thousand airmen?"

Weeks later, the Luftwaffe began its daylight raids – the Battle of Britain had begun. Hurricanes and Spitfires formed the backbone of Fighter Command's squadrons, engaging formations of German bombers and their fighter escorts. On 13 August the Luftwaffe began targeting airfields with the aim of destroying the RAF's ability to fight. However, the vital work of a vast support network, and the early warning of the Radar system, meant Fighter Command's planes were kept in the air. Crucially, they could afford to remain in combat for much longer than their opponents, who had to reserve fuel for the return across the English Channel.

Also instrumental in the RAF's victory were the contributions of the many airmen from across the Empire – as well as other Allied nations – who flew in Fighter Command squadrons. One of the most successful units during the Battle of Britain was 303 Squadron, a majority of whose pilots were Polish, forced into exile by the occupation of their country in 1939.

The top-scoring fighter ace of 303 was a Czech national named Josef František, who shot down 17 planes. Thanks to Fighter Command's pilots, referred to by Churchill as 'the few' in his famous speech, by late September the Luftwaffe had abandoned its daylight raids. It instead focused on night-time sorties, beginning the Blitz of Britain's cities and industrial centres.

The Women's Auxiliary Air Force

The Women's RAF was originally formed at the same time as the RAF in 1918, but it was discontinued in 1920 as the requirements of war ceased. However, with conflict looming once again in 1939, the Women's Auxiliary Air Force (WAAF) was formed to fill crucial roles to keep the air force flying. As well as serving as radar technicians, wireless operators, engineers and in other support roles, women also became pilots in the Air Transport Auxiliary, ferrying personnel, resources and planes across the country.

During the Battle of Britain, six WAAF personnel received the Military Medal for bravery. After the British Government enacted the conscription of women in 1941, the WAAF grew to a high of 182,000 by 1943.

WAAF personnel undergo inspection at a Fighter Command base

The life of Britain's RAF

1 April 1918
The Royal Air Force is officially formed, making it the world's first dedicated air force, independent of the Navy and Army.

1 April 1918
The Women's Royal Naval Service and Women's Army Auxiliary Corps are merged to form the Women's Royal Air Force.

19–20 May 1918
84 RAF aircraft successfully fight off a German bombing raid over Britain, shooting down seven enemy airships.

14–15 June 1919
RAF pilots John Alcock and Arthur Whitten Brown successfully complete the first non-stop flight across the Atlantic.

1 January 1920
An apprenticeship scheme is launched to train young technicians, engineers and a range of other RAF support roles.

RAF uniforms

Air crew gear has transformed from rudimentary to high-tech in under a century

Warm coat
With no enclosed cockpit, pilots had to wear thick wool- or fur-lined coats to keep warm at high altitudes.

Headgear
Motoring gear was largely adopted for pilots' use. Although not much use against high-speed crashes, these helmets were handy in a bumpy landing.

Oxygen mask
To avoid the effects of altitude sickness, aircrews each wore a mask attached to their helmet, which supplied a steady flow of oxygen.

Helmet display
Modern helmets can display targeting and other information direct onto the pilot's visor and can be fitted with mounted displays for thermal imaging or night vision.

Respirator
Modern respirators provide protection from biological and chemical weapons by pressurising a hood worn beneath the helmet and sealed at the neckline.

Thermal suit
During WWII, bomber crews wore specially designed electrically heated suits to cope with the long periods of high-altitude flying.

Thick boots
At altitudes of over 4,500m, temperatures could drop to -30˚C. Thick leather fur-lined stockings were worn to keep out the cold.

Flame-resistant
The suit was made from flame-resistant material and was also designed to be buoyant in case of a bail out over water.

Anti-G
Modern flight suits are specially designed to counter the effects of G-force pressure at high speeds by normalising blood flow and breathing conditions.

The many supporting the few

Role 1... Ground crew
Each fighter plane was assigned its own ground crew team to re-fuel, repair and re-arm the aircraft between sorties. Crews would work tirelessly to repair aircraft and get them back into the battle.

Role 2... Radar operators
Dozens of manned stations positioned around the coastline made up Britain's Chain Home Radar network. This acted as an early warning system to detect and report incoming enemy aircraft.

Role 3... Factory workers
With thousands of men called up to serve, millions of women were called upon to power Britain's war industry. Factory assembly lines worked around the clock to produce planes, tanks, shells, artillery, weaponry and other military materiel.

Role 4... Anti-aircraft
Over 1,790 light and medium anti-aircraft guns were on hand to engage enemy aircraft. Over 4,000 searchlights and 1,400 barrage balloons were also deployed to defend major cities.

9 March–1 May 1925
The first independent RAF operation is carried out in the form of bombing raids over Waziristan, Pakistan.

29 October 1925
The Observer Corps is formed, tasked with detecting, identifying and reporting all aircraft movements over Britain from the ground.

5 March 1936
The Supermarine Spitfire makes its first successful flight.

14 July 1936
RAF Bomber, Fighter and Coastal Command are formed, separating the main branches of the air force.

28 June 1939
The Women's Auxiliary Air Force is formed.

10 July 1940
The Battle of Britain begins, with the Luftwaffe attempting to destroy the RAF's capability to defend Britain.

UNLEASHING THE WHIRLWIND

In 1942, Sir Arthur 'Bomber' Harris stated that Nazi Germany would 'reap the whirlwind' in response to its devastating bombing campaigns throughout Europe. Between 1939 and 1945 Bomber Command carried out over 360,000 missions across Europe, targeting military installations, factories, infrastructure and eventually cities. These missions aimed to disrupt and destroy Germany's war industry, as well as displace and demoralise its civilians.

Up to 1,000 bombers would take part in each of these raids in order to overwhelm air defences and enemy fighters. Waves of aircraft, most often Lancaster bombers, would be led by one or two smaller pathfinder planes, which would mark the target at which the rest could aim.

Throughout the war Bomber Command developed newer, deadlier payloads to deal with different targets. Industrial targets were showered with a combination of incendiary and 2,000-kilogram explosives, while reinforced submarine pens were hit with ten-ton bombs.

Several German cities suffered immeasurable damage in the whirlwind of Bomber Command's raids. Estimates of civilians killed during the campaign range from 300,000 to 1 million, and many more were made homeless. Cologne, Hamburg, Dresden and other major cities suffered some of the worst destruction in the European theatre of WWII. Witnesses recalled flaming vortexes whipping through the streets as firebombs turned neighbourhoods into infernos. However, bomber crews did not escape unscathed, with over 55,000 killed, equating to a 44 per cent casualty rate for Bomber Command.

THE JET AGE

With the start of the Cold War, Britain and its allies continued to develop and adapt to the new era of warfare dominated by the threat of nuclear arsenals. Although Nazi Germany had already deployed the world's first jet fighter during WWII, the RAF was not far behind with the Gloster Meteor, which took to the sky in the summer of 1944.

By the 1950s the air fleet had undergone its latest radical change, as the reliable old Spitfires and Hurricanes were phased out in favour of the high-speed strike fighter jets, such as the de Havilland Vampire, de Havilland Venom and Hawker Hunter. With top speeds of over 1,100 kilometres per hour, these aircraft were designed for much faster combat scenarios.

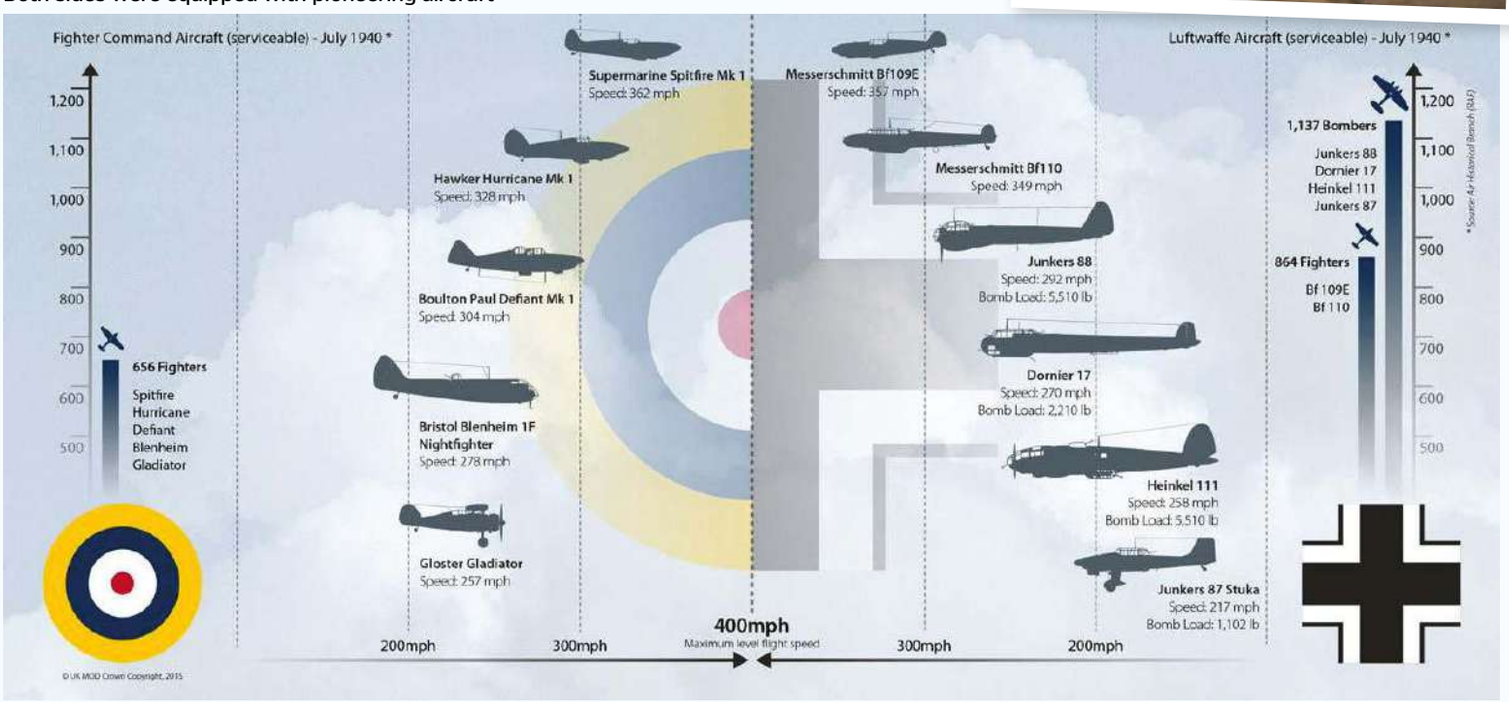
Bomber Command was also equipped with jet power, and its new bombers were capable of altitudes of over 16,000 metres. It was also tasked with operating Britain's nuclear strike capability, and the new 'V-force' bombers (the Vulcan, Victor and Valiant) were kept in a state of constant readiness should war break out.

Although a nuclear strike was thankfully never required, during the Falklands War the Vulcan did take part in one of the longest-range missions in RAF history. Operation Black Buck was a series of bombing runs launched from

The Sopwith Camel was the RAF's WWI-era bi-plane. It was used to shoot down Zeppelin airships in 1918

RAF vs Luftwaffe

Both sides were equipped with pioneering aircraft



15 September 1940
Fighter Command successfully repels the largest German raid over Britain, bringing down 176 enemy aircraft.

5 March 1943
Britain's first operational jet aircraft, the Gloster Meteor, makes its first flight.

16–17 May 1943
Lancaster bombers from 617 Squadron successfully destroy two dams in the Rhine Valley using specially invented bouncing bombs.

30–31 March 1944
Bomber Command suffers its worst losses in a single night, losing 95 aircraft during a raid on Nuremberg.

31 October 1945
The Sikorsky R-4 helicopter, the world's first mass-produced helicopter, is air tested at RAF Andover.

1964
The Red Arrows, the Royal Air Force Aerobatic Team, is established.

Famous RAF pilots

1. Leonard Cheshire

Leader of 617 Squadron, the unit that took part in the famous Dambusters raid, Cheshire became the most decorated Bomber Command pilot when he received the Victoria Cross in 1944.

2. Adolph 'Sailor' Malan

Born in South Africa, Malan joined the RAF in 1935 and commanded 74 Squadron during the Battle of Britain. He achieved 27 confirmed kills in the battle and later created his own 'Ten Rules for Air Fighting'.

3. William 'Billy' Bishop

After joining the Royal Flying Corps in 1915, Bishop achieved 72 victories during WWI and also received the Victoria Cross. He later became an air marshal with the Royal Canadian Air Force during WWII.

4. Mary Ellis

After earning her pilot's licence in 1939, Ellis joined the Air Transport Auxiliary and soon became one of the first female Spitfire pilots. Although she was not strictly in the RAF itself, she delivered over 1,000 planes during the war.

5. Witold Urbanowicz

Already a battle-hardened pilot, Urbanowicz commanded the majority-Polish 303 Squadron during 1940. He achieved 15 victories during the battle and was awarded the Distinguished Flying Cross.

The Battle of Britain

In 1940 the Luftwaffe attempted to destroy the RAF, but Britain was ready with several defensive measures

Radar

A network of Radar towers called Chain Home lined Britain's coastline, detecting and reporting enemy aircraft up to 193km away.

Fighter Groups

The defence of Britain was split into four sections – Fighter Groups 10 to 13. Group 11 was the largest and bore the brunt of Luftwaffe attacks.

Anti-aircraft artillery

Fighter groups controlled all anti-aircraft batteries and barrage balloons in their area, co-ordinating to engage enemy formations effectively.

Dowding System

Incoming enemy numbers and locations would be reported to Fighter Command HQ, which would direct the relevant Fighter Group to scramble pilots in that area.

Dogfighting tactics

Pilots on both sides used the glare of the Sun and cloud cover to conceal their approach, and diving attacks from higher altitudes caught the enemy off guard.

RAF Fighter Command
- Command Headquarters
- Group Headquarters
- Sector station
- Fighter base
- Low level radar station
- High level radar station
- Towns bombed

German Bases
- Bomber base
- Fighter base

Glasgow, Belfast, Newcastle, Sunderland, Middlesbrough, Fighter Command Group 13, Luftlotte 3 From Norway and Denmark, Range of high level radar, Range of low level radar, Hull, Liverpool, Manchester, Sheffield, Nottingham, Fighter Command Group 12, Norwich, Birmingham, Coventry, Ipswich, Amsterdam, Rotterdam, Swansea, Cardiff, Bristol, Fighter Command Group 11, LONDON, Canterbury, Calais, Antwerp, Ghent, Southampton, Fighter Command Group 10, Portsmouth, Exeter, Plymouth, Lille, BELGIUM, Luftlotte 2, Amiens, Cherbourg, Le Havre, Luftlotte 3, Paris, FRANCE, Rennes

30 April 1968
RAF Bomber and Fighter Command merge to form Strike Command.

1 April 1969
The world's first vertical take-off and landing aircraft, the Harrier, enters RAF service.

30 April–1 May 1982
Vulcan jets attack targets on the Falkland Islands, conducting at the time the longest-range bombing operation in history.

1990
RAF aircraft take part in Operation Granby – British operations during the 1990–91 Gulf War.

2007
The first RAF operations using Reaper MQ-9A drones are conducted in Afghanistan.

2018
RAF 617 Squadron is re-formed, equipped with the F-35B Lightning.

Ascension Island in the central Atlantic, covering 6,100 kilometres to the target: Port Stanley airfield on the Falklands. This was followed up with attacks from nine Sea Harriers, another iconic British aircraft of the era that was capable of vertical take-off and landing.

RAF 100

Since the turn of the century, the RAF has kept in step with the advances in unmanned aircraft systems and joined the MQ-9A Reaper drone programme in 2004. Although the concept of unmanned air vehicles (UAVs) is nothing new, the capabilities of this latest leap in technology marks the start of a new era for the world's air forces. Reaper drones can conduct precise intelligence gathering and offensive missions, identifying and targeting enemy positions, all while under the control of a ground crew often thousands of miles away. The next generation of drone systems, the Predator SkyGuardian, has already made history as the first medium-altitude long-endurance (MALE) craft to cross the Atlantic, arriving at RAF Fairford in July 2018.

For some, these unmanned systems mark the future of aerial warfare. However, for now at least the core of the air force remains its piloted strike fighters. In 2018, the legendary 617 Squadron, the Dambusters, was reformed and received its first F-35 Lightning jet fighters. These aircraft reflect the multi-role demands of the modern era, with stealth design features, electronic warfare capability and advanced avionics enabling the F-35 to take on nearly any mission. The Fleet Air Arm will also be deploying the short take-off and landing variant of the F-35 for use with the Queen Elizabeth class aircraft carriers.

During the centenary year of the RAF celebrations commemorating the milestone were held throughout Britain. This included a country-wide tour of some of the force's most famous machines. On 10 July over 100 aircraft took part in a spectacular flypast over London. This included modern aircraft such as the Eurofighter and F-35, following on the tails of historic icons such as the Spitfire and Lancaster bomber (all part of the Battle of Britain Memorial Flight). The Red Arrows also took part, as well as the Chinook and a range of utility helicopters. This one display represented nearly 100 years of military history, demonstrating the RAF's greatest accomplishments and embodying its motto, 'Per ardua ad astra': Through adversity to the stars.

The remotely controlled Reaper drone came into RAF service in 2004

Inside a Supermarine Spitfire

The RAF's iconic aircraft was one of the greatest fighter planes of WWII

Cockpit
The airframe was recognisable for its aerodynamic, domed canopy, although without a pressurised cockpit pilots could not achieve higher altitudes.

The Eurofighter Typhoon entered RAF service in 2006 and remains active in several squadrons

Hurricane pilots rush to their machines after being scrambled for take-off, August 1939

Members of 106 Squadron, Bomber Command, pose in front of a Lancaster Bomber, March 1943

Engine
A V-12 piston Rolls-Royce Merlin power plant enabled the pilot to reach speeds of up to around 600kph.

Fuel
The plane's tank could hold 386L of fuel, providing a range of 1,826km but a much shorter effective combat range.

Armament
Mounted on the wings were two Hispano 20mm cannons and four Browning 7.7mm machine guns.

BRITAIN'S NEW "SPITFIRE"

With an even more powerful Rolls-Royce "Merlin" engine, the "Spitfire" enters the lists again, re-engined and re-armed. It is now armed with two cannon and four machine guns. The official speed of "Spitfire I" was over 366 m.p.h. at 18,500 feet. The rate of initial climb was 2,300 feet per minute. Points in "Spitfire" design are its all-metal construction, stressed metal covering, outwards retracting undercarriage. Fixed tail wheel, radiator under starboard wing, are other points. Wing-span is 36 feet 10 inches; height, 11 feet 5 inches. The Supermarine "Spitfire I" was evolved from the seaplane which won the Schneider Trophy, for the third successive time and outright in 1931. "Achtung Schpitfeuer" are still the last words many a Nazi airman will hear.

1 METAL-COVERED WINGS
2 CANNON
3 THREE-BLADED CONSTANT-SPEED AIR SCREW
4 TANK
5 ROLLS-ROYCE "MERLIN" ENGINE
6 EXHAUSTS
7 OIL TANK
8 ENGINE BEARERS
9 CARBURETTOR AIR INTAKE
10 SUPERCHARGER
11 FIREPROOF BULKHEAD
12 RETRACTED UNDERCARRIAGE (STARBOARD)
13 METAL RIBS
14 RADIATOR
15 MACHINE GUNS
16 AILERON
17 LOWER FUEL TANK } Total Fuel Load — 85 Gallons
18 UPPER FUEL TANK }
19 INSTRUMENT PANEL
20 CONTROL LEVER
21 FIRING TRIGGER
22 GUN SIGHT
23 MIRROR
24 SLIDING HOOD
25 UNDERCARRIAGE CONTROL HANDLE
26 LONGERON
27 BATTERY BOX
28 PARACHUTE FLARE
29 METAL RIBS
30 DITTY BOX
31 STRINGER
32 RADIO
33 AERIAL
34 FIN
35 RUDDER
36 ELEVATORS
37 TAIL WHEEL

LENGTH 29 ft. 11 in.
SPAN OF PLANES 36 ft. 10 in.

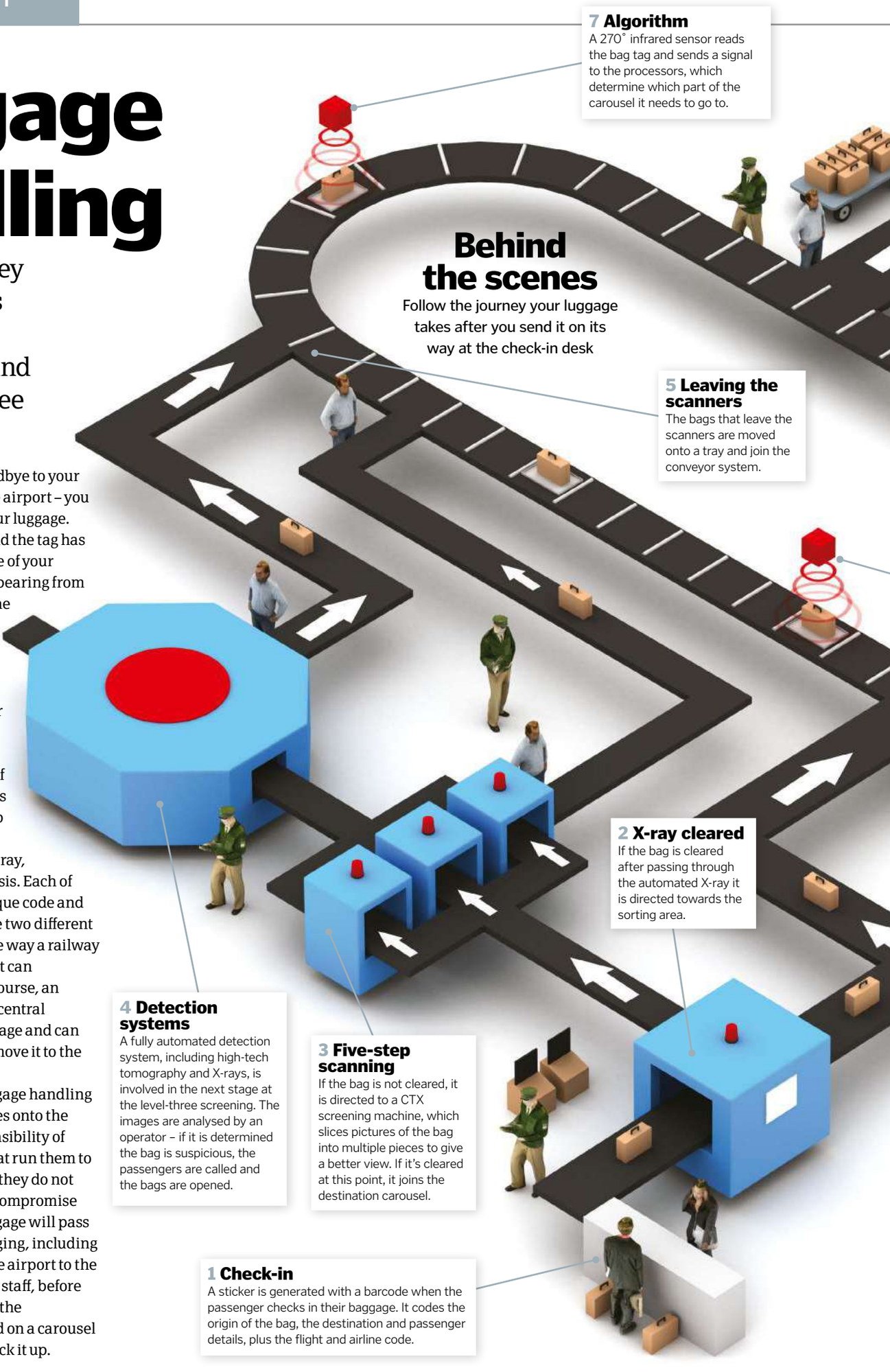
Baggage handling

Discover the journey your luggage takes while you pass through security and browse the duty free before boarding

You don't just wave goodbye to your friends or family at the airport – you also say farewell to your luggage. After you've had it weighed and the tag has been attached, the last you see of your possessions is your bag disappearing from sight on a conveyor belt into the labyrinth of the baggage handling system. You won't be reunited with it until you reach your destination (hopefully). But how does your bag navigate the hidden network of bags, travelling at high speed along thousands of rollers and motors? It all comes down to that tag that you wrap around the handle.

Your baggage is placed in a tray, which is loaded on a tray chassis. Each of these components have a unique code and the computer system pairs the two different numbers together. In the same way a railway track has moveable points that can manually change the train's course, an airport baggage system has a central computer that tracks the baggage and can change points in the track to move it to the correct destination.

However, the job of the baggage handling system isn't just to get suitcases onto the correct flights – it is the responsibility of these systems and the staff that run them to screen each bag to make sure they do not contain anything that might compromise flight safety. Each piece of luggage will pass through several stages of imaging, including X-rays, as it travels through the airport to the gate to be manually loaded by staff, before – hours later – it's unloaded at the destination airport and placed on a carousel waiting for you to come and pick it up.



Behind the scenes

Follow the journey your luggage takes after you send it on its way at the check-in desk

7 Algorithm
A 270˚ infrared sensor reads the bag tag and sends a signal to the processors, which determine which part of the carousel it needs to go to.

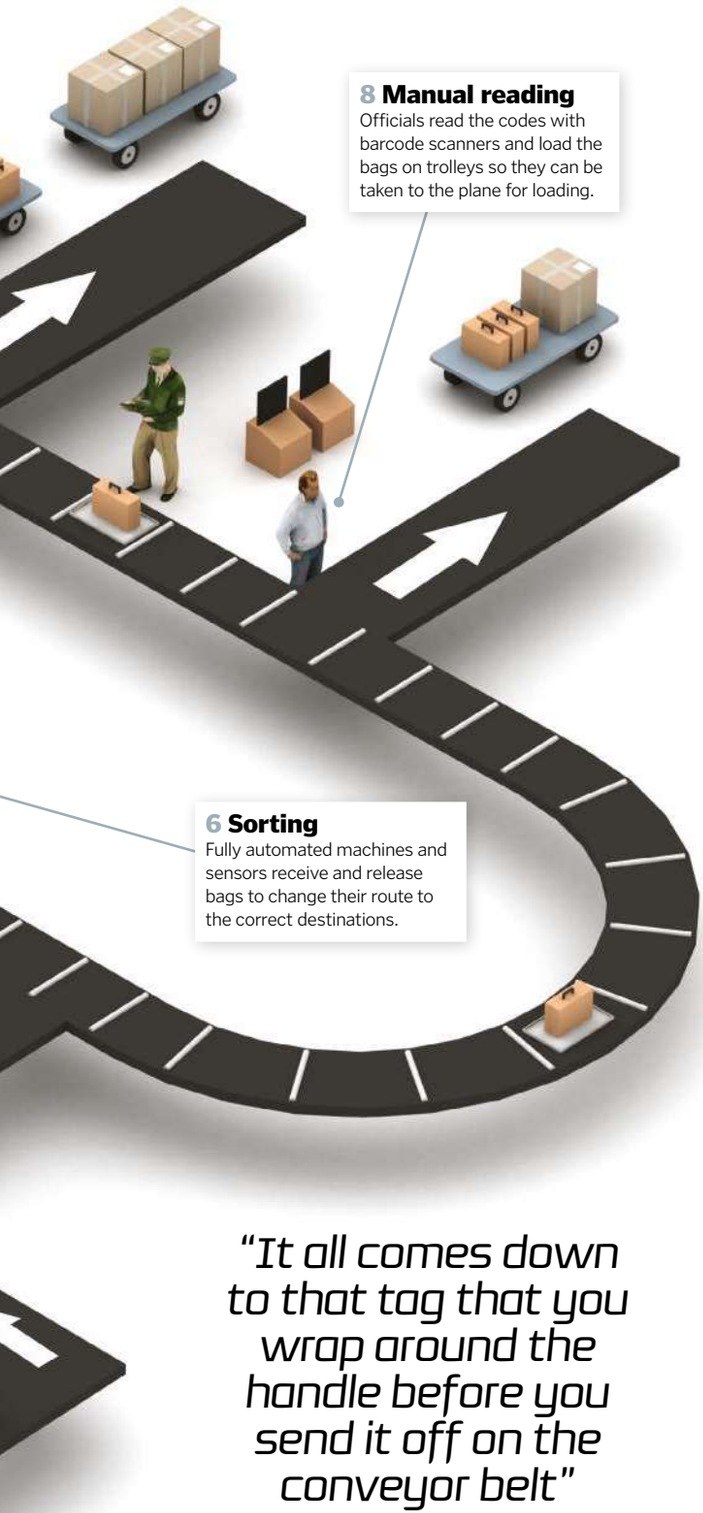
5 Leaving the scanners
The bags that leave the scanners are moved onto a tray and join the conveyor system.

2 X-ray cleared
If the bag is cleared after passing through the automated X-ray it is directed towards the sorting area.

4 Detection systems
A fully automated detection system, including high-tech tomography and X-rays, is involved in the next stage at the level-three screening. The images are analysed by an operator – if it is determined the bag is suspicious, the passengers are called and the bags are opened.

3 Five-step scanning
If the bag is not cleared, it is directed to a CTX screening machine, which slices pictures of the bag into multiple pieces to give a better view. If it's cleared at this point, it joins the destination carousel.

1 Check-in
A sticker is generated with a barcode when the passenger checks in their baggage. It codes the origin of the bag, the destination and passenger details, plus the flight and airline code.



"It all comes down to that tag that you wrap around the handle before you send it off on the conveyor belt"

Barcodes on the luggage tag, tray and chassis are registered together to send the suitcase on its journey

Suitcases are manually loaded once they arrive at the gate, but most of the handling process is automated

Upon arrival, bags are placed at baggage claim, where they will circulate on a carousel until they are picked up

Luggage lowdown

The fastest baggage handling systems can achieve a top speed of

10 METRES PER SECOND

IN ADDITION TO STRICT WEIGHT LIMITS, AIRCRAFT ALSO HAVE BALANCE REGULATIONS TO KEEP THE AIRCRAFT SAFE

7%

The percentage of bags that are permanently lost or stolen according to the SITA

RULES AND REGULATIONS ABOUT LUGGAGE (INCLUDING LABELLING AND WEIGHT RESTRICTIONS) ARE GOVERNED BY THE WARSAW CONVENTION

In 2016, an estimated

21.6 MILLION

bags were lost either temporarily or permanently

IN 2020, IT IS PREDICTED THE BAGGAGE HANDLING MARKET WILL BE WORTH

$9.36 BILLION

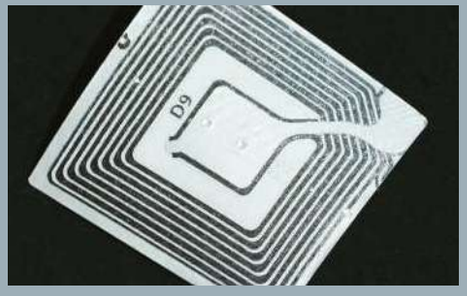
State-of-the-art Siemens Technology in Beijing Capital International Airport's Terminal 3 can process

19,200 items per hour

Barcodes and the future of luggage tags

Airports use continuous two-width barcode symbology encoding digits, which are printed using a barcode printer onto adhesive thermal paper. This is then attached to the bag at check-in. But this technology isn't always reliable. If they are not printed properly or they become dusty, the hand-held scanners or in-line arrays are unable to read them.

The baggage handling industry is investigating better alternatives, such as radio-frequency identification (RFID) technology, and offers a 99.9 per cent accurate read rate for tracking bags. McCarran International Airport in Las Vegas, US, and Hong Kong International Airport have both made the move over to this more modern technology. It is thought that RFID tagging could reduce the number of lost bags by up to 25 per cent.



Radio-frequency identification (RFID) uses electromagnetic fields to identify and track objects

How to recycle a car

From rebuilt engines to fuel for the steel industry, there is life after death for cars of the scrapyard

Your first car was probably a bit rusty, a bit clattery, but it got you where you needed to go for a few years until it started to fall apart. All cars eventually die, but they retain a level of value, even when nothing works anymore. They are destined for the scrapyard, where they'll be sliced up, churned and spat out as cubes of metal. But this isn't the end of your car's life – it's the beginning of a new one.

The parts inside your old car can be removed and recycled or repurposed. These parts will be removed before being compressed and stacked with the contents of other cars that are set for the crusher. They will then in time go on to become part of a new car or product – almost everything, right down to the engine, can be reused.

The process requires a lot of complicated stages of extracting parts and disposing of hazardous materials, starting with the removal of the battery, tyres and catalytic converter, followed by draining all of the vehicle's fluids. The highest-value parts may be removed and sold as a new restored product or as a second-hand part. This historically labour-intensive process has been made more efficient with the introduction of machine-based vehicle-recycling.

After the hazardous chemicals, including airbag propellant and mercury, are removed, only an empty shell of the car remains, which is crushed into a cube or totally flattened before being transported to an industrial shredder. It is often then remade into new car parts.

In the UK it is estimated that 2 million cars are scrapped every year

The crushed up, torn apart shell is the last part of a car to be melted down and recycled

5 FACTS ABOUT...

HOW YOUR CAR TYRES ARE RECYCLED AND REPURPOSED

1 Cement manufacturing
Old tyres can be used as fuel in the manufacturing of cement, providing energy and economical benefits, and an environmentally friendly way for the complete and safe destruction of used tyres.

2 Building material
Tyres can make an affordable building material in sustainable housing. The tyres are filled and compacted with earth to provide strong, long-lasting insulated walls.

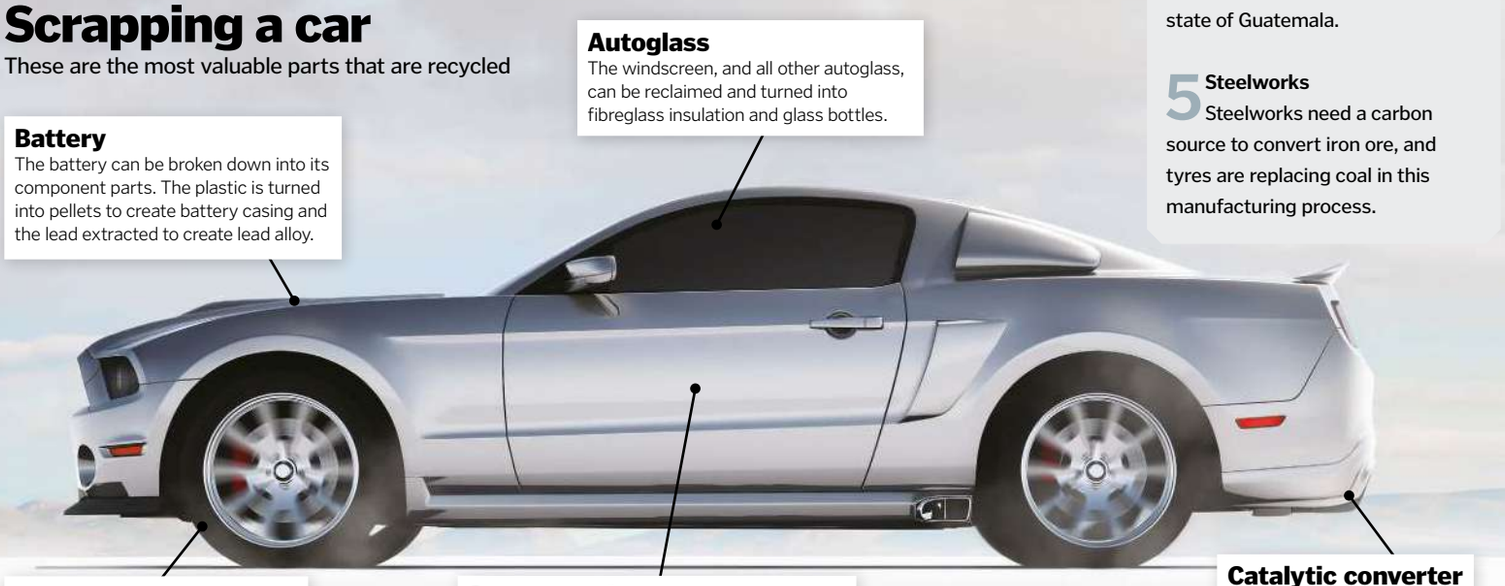
3 Tyre-derived aggregate
Tyre-derived aggregate are thinly sliced remnants of tyre that can be used in the engineering industry, particularly for vibration-damping material on railway lines.

4 Soles of shoes
New shoe products including flip-flops and trainers are often made from recycled tyres, such as huaraches in Mexico and caite sandals in the Central American state of Guatemala.

5 Steelworks
Steelworks need a carbon source to convert iron ore, and tyres are replacing coal in this manufacturing process.

Scrapping a car

These are the most valuable parts that are recycled



Battery
The battery can be broken down into its component parts. The plastic is turned into pellets to create battery casing and the lead extracted to create lead alloy.

Autoglass
The windscreen, and all other autoglass, can be reclaimed and turned into fibreglass insulation and glass bottles.

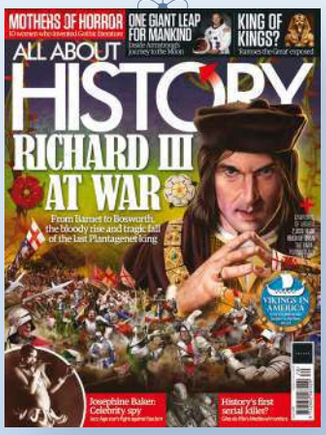
Tyres
Tyres are often turned into rubberised asphalt for motorways, which reduces noise pollution.

Scrap metal
Every metal part in your car – including fenders, door handles and radiators – can be melted down to create new metal products.

Catalytic converter
Precious metal, such as platinum, is removed from the catalytic converter and recycled for jewellery.

OFFER ENDS 31 DECEMBER 2018

FROM £12.50 EVERY 3 MONTHS
(€90/$135 PER YEAR)

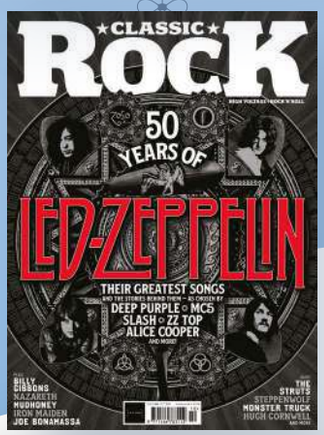


FROM £8.75 EVERY 3 MONTHS
(€70/$87 PER YEAR)

FROM £8.75 EVERY 3 MONTHS
(€70/$87 PER YEAR)

The perfect gift from just £7.50*

FROM £7.50 EVERY 3 MONTHS
(€70/$87 PER YEAR)



FROM £8.75 EVERY 3 MONTHS
(€86/$95 PER YEAR)

FROM £9.99 EVERY 3 MONTHS
(€60/$62 PER YEAR)

Delivery included in the price

Free personalised e-card when buying for someone else

Buy as a gift or treat yourself!

Choose from a ***huge range of titles***

SEE THE FULL RANGE AND ORDER ONLINE

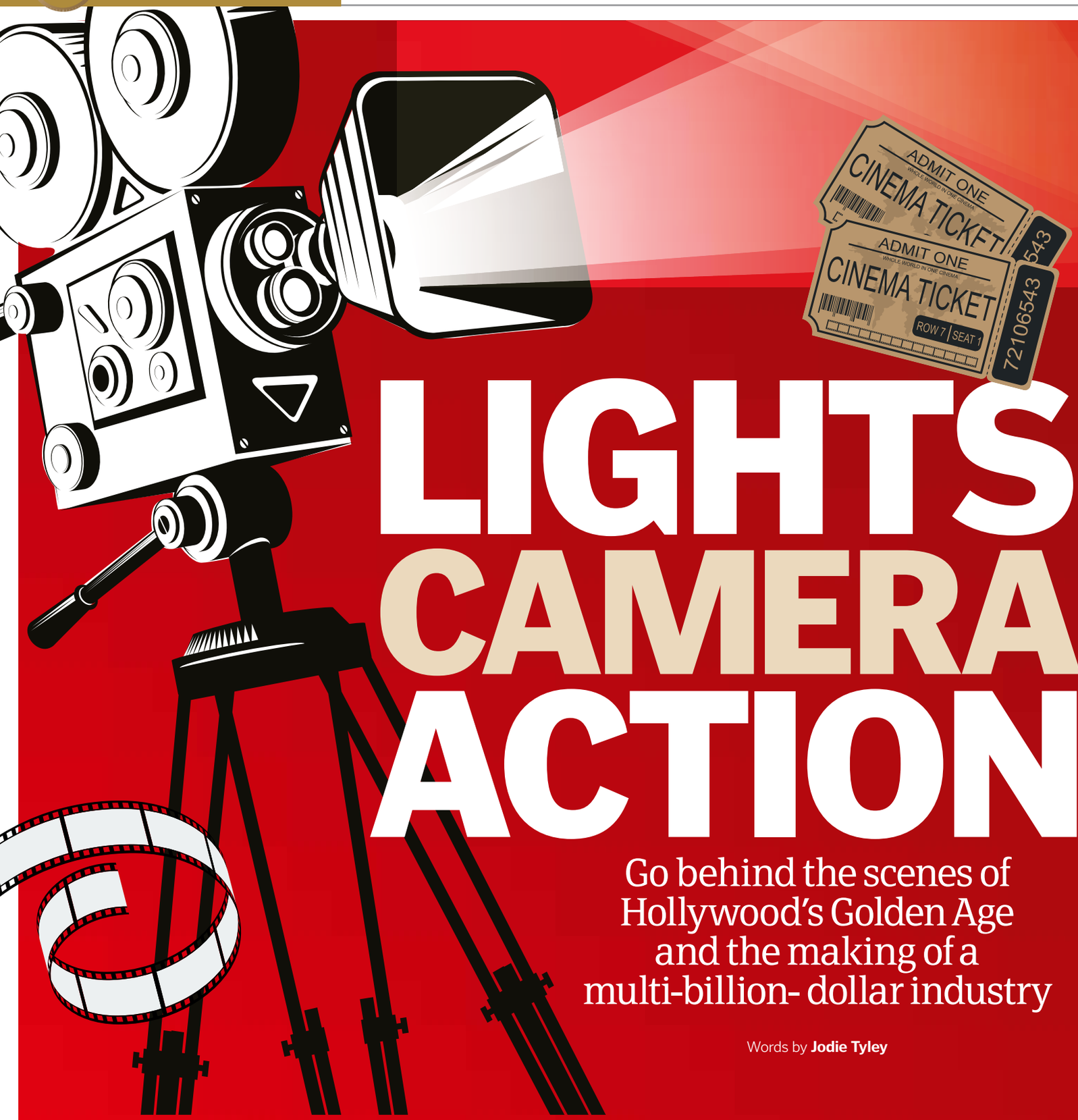
www.myfavouritemagazines.co.uk/xmas187

ORDER HOTLINE: 0344 848 2852

PLEASE QUOTE XMAS187 WHEN ORDERING BY PHONE

LINES ARE OPEN MONDAY–FRIDAY 8AM TO 7PM AND SATURDAY 10AM TO 2PM (GMT)

***Terms and conditions:** Savings calculated against the full RRP (single issue price x frequency). Dollar prices quoted are for the United States, other global territory dollar pricing may vary. This offer is for new subscribers only. You can write to us or call us to cancel your subscription within 14 days of purchase. Your subscription is for the minimum specified and will expire at the end of the current term. Payment is non-refundable after the 14-day cancellation period unless exceptional circumstances apply. Your statutory rights are not affected. Prices correct at point of print and subject to change. Full details of the Direct Debit guarantee are available on request. For full terms and conditions please visit **bit.ly/magtandc**. Offer ends 31 December 2018.



LIGHTS CAMERA ACTION

Go behind the scenes of Hollywood's Golden Age and the making of a multi-billion- dollar industry

Words by **Jodie Tyley**

The year is 1929 and Hollywood's Roosevelt Hotel has opened its doors to the first Academy Awards. There's no red carpet and no viewers watching at home (it wouldn't be aired on television until 1953). The ceremony lasts 15 minutes and the 270 guests already know who's won because the results were announced months earlier. A far cry from today's media circus, the inaugural awards was a private dinner for filmmakers and stars held to celebrate an industry in the midst of its Golden Age.

From the 1920s to the 1960s, one Los Angeles neighbourhood became the movie capital of the world. It was a period of huge growth, both in terms of movie milestones and the emergence of major motion picture studios. But why Hollywood? Well for one thing the long daylight hours of southern California and the variety of landscapes, from desert to forests, made it an ideal shooting location. Land was also cheap – perfect for setting up studio backlots – and taxes were low. It was a no-brainer, and by 1915, 60 per cent of US film production was based there. Even world wars and the worst economic event in history couldn't prevent the meteoric rise of this star-studded industry – one that

actually owes more to science and technology than glitz and glamour.

By the time of that very first Academy Awards ceremony the movie world was moving at a blistering pace and the era of silent film was coming to an end. Of course, the term 'silent movie' is a misnomer, because these films were never viewed in complete silence. Theatres employed musicians to play live, ranging from solo pianists to full-blown orchestras, and the film distributors would often provide cue sheets to help their performance.

Despite new technology making it possible to synchronise audio with visuals, Hollywood was hesitant. Making the costly conversion to sound would damage overseas appeal by creating language barriers, and what would happen to the studios' archive of silent movies? It was a risk, but one that film producer Sam Warner convinced his siblings to take. Warner Brothers was a small studio with big ambitions, and Sam believed that synchronised soundtracks could boost their business.

Don Juan (1926) was the first film to feature a score and sound effects using the sound-on-disc system Vitaphone. The record was played on a turntable, which was connected to the film projector by a motor that controlled the speed. The film was a critical and commercial success, and the following year the studio released the first movie with dialogue when Al Jolson ad-libbed in between musical numbers in *The Jazz Singer*. The silence of cinema was broken when he called to the orchestra, "Wait a minute, wait a minute. You ain't heard nothin' yet!"

The Wizard of Oz was released in glorious Technicolor

These so-called 'talkies' were a sensation, but those in front of the camera were less enamoured with the new medium. Actor Mary Pickford famously said that adding sound to pictures was "like putting lipstick on the Venus de Milo". She wasn't the only one who thought movie stars should be 'screened not heard' either, as the talkies spelled disaster for many careers. Vilma Banky's image as the all-American sweetheart was shattered when audiences discovered she spoke with a Hungarian accent. Charlie Chaplin, on the other hand, chose to stay tight-lipped and didn't appear in a speaking role until 1940. The plot to *Singin' in the Rain* (1952) poked fun at this difficult transition, as Gene Kelly's character and his co-star are forced to adapt to the new era.

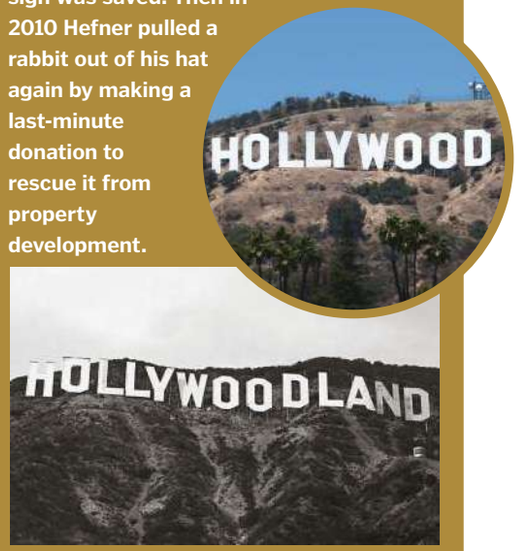
Talkies presented technical challenges too. Early microphones had such limited range that actors had to speak directly into them, restricting performances. The mics were also omnidirectional and picked up unwanted sound from the recording equipment. Cameras were confined to glass booths, which only allowed the lens to be tilted 30 degrees on a tripod. This, combined with the actors' inability to walk and talk, made these early sound films very static. The solution: soundproof camera casings called 'blimps', which enabled operators to follow the action, mounting the cameras on wheeled carts called 'dollies'. Microphones were then hung from boom arms above the actors.

The success of sound saved American cinema, even when the 1929 Wall Street Crash

A sign of the times

Those iconic letters on the hillside are synonymous with movies and stardom, but it was originally an advert for a housing development. *Los Angeles Times* publisher Harry Chandler was branching out into real estate and splashed out on the $21,000 'Hollywoodland' sign in 1923. The original 13 wood and iron letters were over 13 metres tall and around nine metres wide, rigged together by scaffolding and telephone poles. No one could miss it – especially with the thousands of light bulbs flashing around the letters like a mob of paparazzi.

However, by the mid-1940s the sign was on the blink. Some repairs and the removal of the last four letters bought it some time, but by the 1970s it needed completely rebuilding. This time it was celebrities that saved it. *Playboy* founder Hugh Hefner hosted a lavish fundraiser where letters were 'auctioned' and the sign was saved. Then in 2010 Hefner pulled a rabbit out of his hat again by making a last-minute donation to rescue it from property development.



The Hollywood sign is on Mount Lee, overlooking Hollywood in Los Angeles, US

Movie milestones

1912
Paramount Pictures is established, producing one of the first films to be made in Hollywood (*The Squaw Man*, 1913).

1920
Paramount becomes the first nationwide film distribution company, controlling production, distribution and exhibition.

1922
The Power of Love is the first 3D film to make use of anaglyph glasses with different coloured lenses.

1923
Warner Brothers Studios is founded by siblings Albert, Sam, Harry and Jack.

1924
Movie theatre mogul Marcus Loew establishes Metro-Goldwyn-Mayer (MGM) to ensure a steady supply of good-quality films.

1927
The Jazz Singer – the first feature-length motion picture with synchronised music, singing and dialogue – is released by Warner Bros Pictures.

1928
RKO Radio Pictures is founded and makes motion picture history with *King Kong* (1933) and *Citizen Kane* (1941).

1929
The first Academy Awards ceremony is held in Hollywood. The name Oscar is used a few years later.

1930
The Motion Picture Production Code introduces censorship in the US to prevent films from lowering the moral standard of viewers.

Left: *Singin' in the Rain* (1952) is about the transition from silent films to 'talkies'

bankrupted millions and led to mass unemployment. Theatres saw weekly attendances rise from 60 million in 1927 to 90 million in 1930, financing the mergers and takeovers that followed. The 'Big Five' major film studios emerged: Paramount Pictures, Metro-Goldwyn-Mayer, 20th Century Fox, Warner Brothers Pictures and RKO. It was the birth of the studio system, where companies controlled every aspect of the industry – they produced the films, distributed them and screened them in their cinemas. Actors were even employed on long-term contracts, rather than for specific jobs.

Hot on the heels of sound films came the technology to transform black and white visuals into colour. For decades, filmmakers had hand-painted their footage frame by frame – an expensive and painstaking process – while others used dyes to tint their film. The first successful colour process was Kinemacolor in the early 20th century. It used alternating red and green filters, creating a clever optical illusion where the two colours appeared to be combined. However, this method was far from perfect and the lack of blue was very apparent. The introduction of Technicolor's three-colour camera in 1932 changed all that.

It used the principles of colour photography invented by physicist James Maxwell in 1861 when he produced the first colour photo using red, green and blue filters. Technicolor's camera captured these three colours by using three separate strips of film and combining them to create a full-colour image. One of the most famous showcases of this new technology was *The Wizard of Oz* (1939), which used Technicolor as part of the storytelling when Dorothy leaves her sepia-toned reality for the dazzling land of Oz. Her iconic ruby slippers were silver in the book, but they were not seen as dramatic enough in this new age of cinema.

When studios commissioned Technicolor, they didn't just receive the three-strip camera; the package included a crew of camera operators and a colour consultant, as well as the film stock processed in their labs afterwards.

However, the company's rise had not gone unnoticed, and in 1947 the US Government charged Technicolor with monopolising the production of colour movies. It was part of a campaign that also saw the Department of Justice file a lawsuit against all the major studios for their control over the film industry. Hollywood's studio system was dead.

Companies such as Paramount were forced to sell their theatres, while RKO sold their film rights to TV stations in order to recoup their losses. It was a huge win for the TV industry, which was steadily luring viewers away from the big screen. By the mid-1950s TV networks not had the rights to a catalogue of movies and were also producing their own shows.

Hollywood competed by making even bigger exhibition screens. A new projection system called Cinerama used three synchronised cameras to capture an image three times as wide as a regular film. The Cinerama film was then screened using three projection booths onto a curved screen to create an immersive experience. Studios also experimented with 3D, and the content of their movies became more adult at a time when TV had strict moral regulations. Despite these efforts, the 1960s signalled the end of Hollywood's Golden Age.

Sound effects

Creaking doors, smashing glass, rustling paper – everyday sound effects such as these are reproduced for film and added in post-production. They're known as Foley effects, named after the man who developed the craft. Jack Foley was the sound director at Universal Studios from 1927 to 1960, recording audio of footsteps and other background noises that the microphones couldn't pick up.

Footage would be projected onto the screen and he would create the sound effects in time with the action. To recreate the sound of three men going for a stroll he walked with a cane, and for an entire Roman army marching, he jangled keys (*Spartacus*, 1960). Today, those that follow in his footsteps are called Foley artists, and unlike Jack, they are recognised for their work. During his long career, he never received an onscreen credit.

A pair of Foley artists creating background effects for a radio production in 1945

1933
King Kong uses stop-motion photography, a 46cm model and the travelling matte technique to combine live action with the animated footage.

1935
Fox Film Corporation, formed in 1915 by William Fox, merges with Twentieth Century Pictures to form 20th Century Fox.

1937
The first cel animated film, *Snow White and the Seven Dwarfs*, is released. Walt Disney receives an Academy Honorary Award that features a large Oscar with seven smaller ones next to it.

1939
Gone With the Wind smashes box office records. It is the first colour movie to win an Oscar for Best Picture.

1947
The fear of communism leads to Congress investigating Hollywood. 352 screenwriters, actors and directors are blacklisted.

1948
The US Supreme Court rules that major motion picture companies cannot distribute movies and own theatres without court approval.

1950
The US Government brings an end to Technicolor's monopoly on the three-strip colour film process.

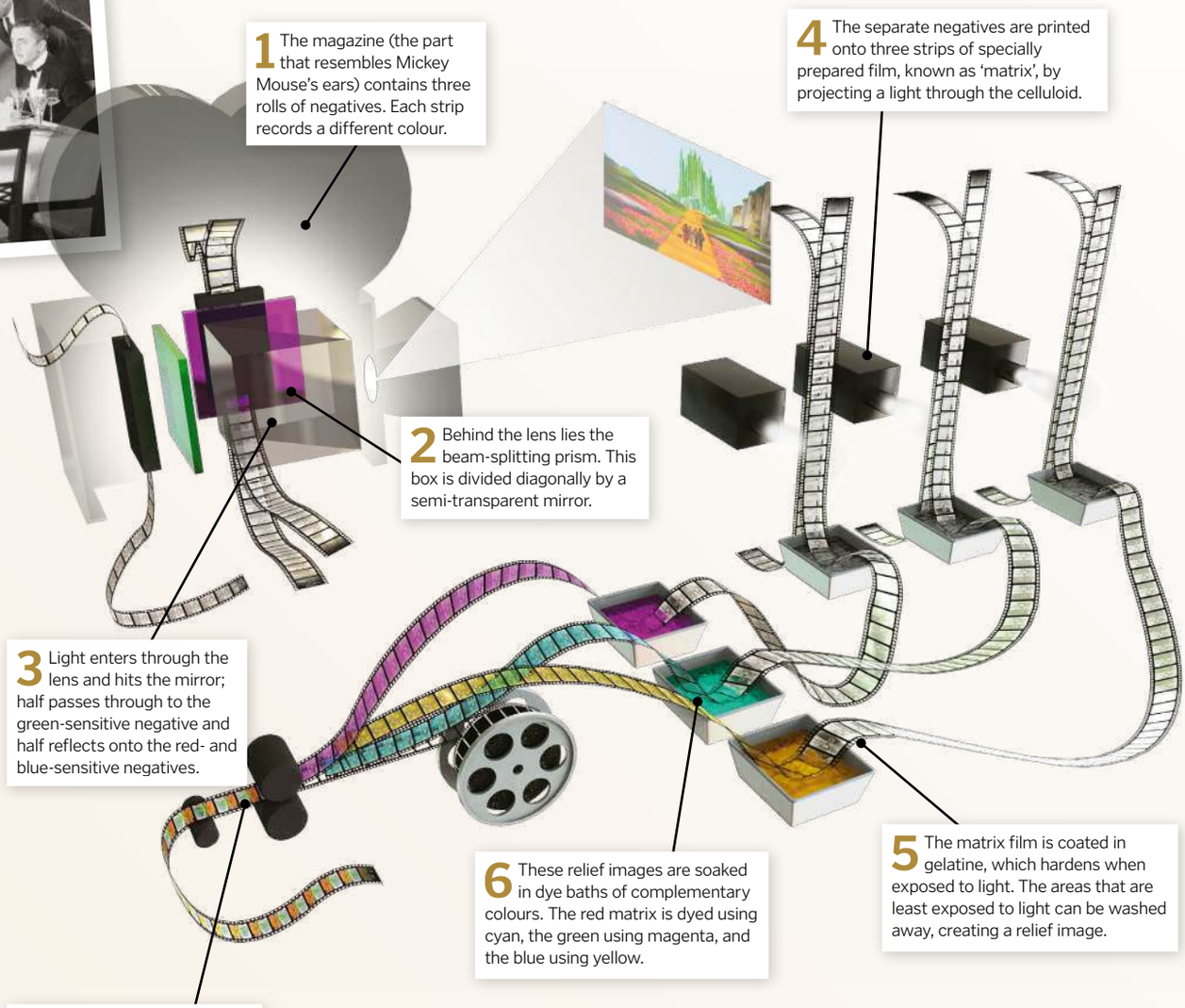
1953
How to Marry a Millionaire, starring Marilyn Monroe, is filmed in CinemaScope – a revolutionary widescreen process with stereophonic sound.

1961
The iconic red carpet is introduced at the Academy Awards.

The tech behind Technicolor

The three-strip camera that revolutionised motion pictures between 1932 and 1954

Behind the scenes of *The Thin Man* (1934)



1 The magazine (the part that resembles Mickey Mouse's ears) contains three rolls of negatives. Each strip records a different colour.

2 Behind the lens lies the beam-splitting prism. This box is divided diagonally by a semi-transparent mirror.

3 Light enters through the lens and hits the mirror; half passes through to the green-sensitive negative and half reflects onto the red- and blue-sensitive negatives.

4 The separate negatives are printed onto three strips of specially prepared film, known as 'matrix', by projecting a light through the celluloid.

5 The matrix film is coated in gelatine, which hardens when exposed to light. The areas that are least exposed to light can be washed away, creating a relief image.

6 These relief images are soaked in dye baths of complementary colours. The red matrix is dyed using cyan, the green using magenta, and the blue using yellow.

7 Each matrix is pressed against a blank film strip for several minutes. After all three transfers are complete the film is ready. The matrices can be used again and again.

Studio secrets

Unravelling some movie mysteries

Stop-motion photography

French magician and filmmaker Georges Méliès turned a pumpkin into a carriage (*Cinderella*, 1899) simply by stopping the camera, changing the object he was filming, and recording again.

Travelling mattes

Cinematographers combined scenes that were shot at different times by concealing part of the film using a 'matte'. In *The Great Train Robbery* (1903), footage of a moving locomotive was combined with footage of a robbery.

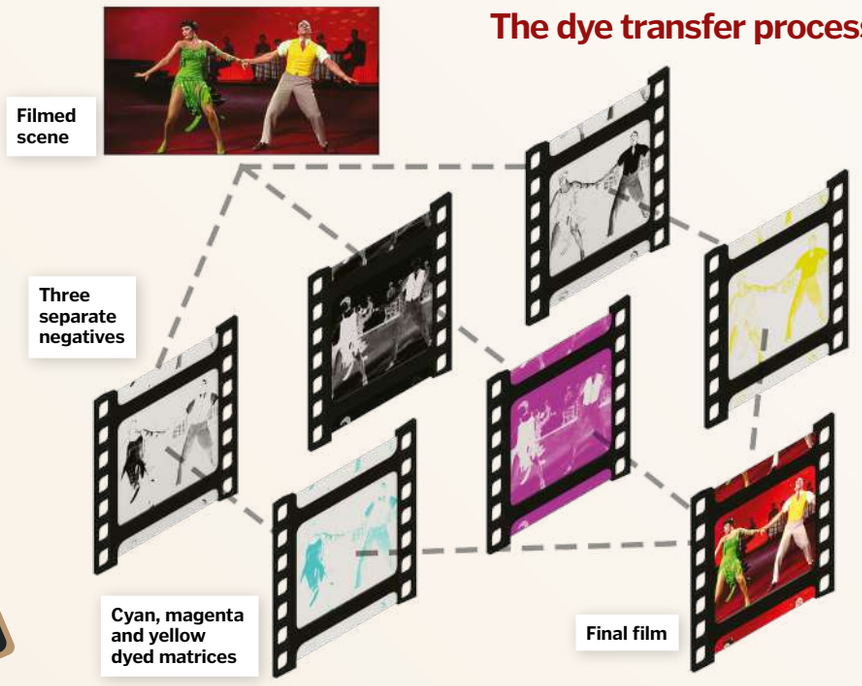
Soft focus

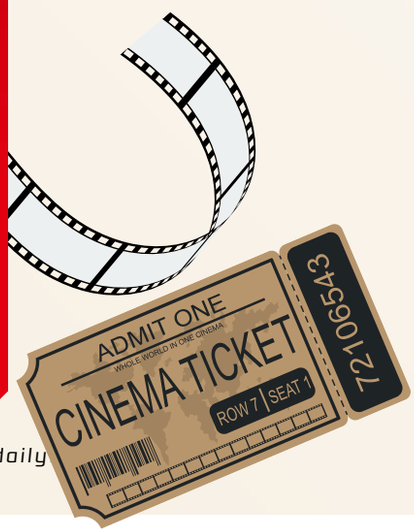
The glamorous glow of silver screen starlets was actually achieved using Vaseline. Applying a little petroleum jelly on the camera lens created a soft-focus, dreamy effect.

Blue-screen

The first ever Technicolor blue-screen featured in *The Thief of Bagdad* (1940). By combining the blue and green negatives to create a solid matte, the film could be combined with new footage shot against a blue-screen.

The dye transfer process





How to we know dinosaurs had feathers?

It turns out that fossils have preserved much more than just bone structure

Most of us have been captivated by the idea of dinosaurs since childhood. Among their numbers stood veracious hunters, towering leaf-eaters, armoured warriors and soaring giants. Add to that the wonder we all felt when we learned that our planet used to belong to them, that before we inherited the (self-awarded) title of Earth's apex animal, it was the reptilian dinosaurs that ruled supreme. In films, books and other illustrations we long envisaged dinosaurs to be clad in scales and thick skin, much like the reptiles of today – such as the terrifying yet magnificent Komodo dragon. A fearsome appearance such as this, after all, is only fitting for a world-conquering group. But would our perception of dinosaurs be altered if we were to learn that some were feathered and some were even fluffy?

Scientists found the first evidence of feathered dinosaurs over 150 years ago with the discovery of the Archaeopteryx. After the animal died, it left behind an immensely well-preserved fossil, and tucked beneath its long arms were the impressions of many familiar curved shapes. The evidence was clear for all to see – the Archaeopteryx had feathers. It wasn't until the 1990s, however, that scientists would uncover much more evidence that showed that Archaeopteryx wasn't alone in its feathery ways. Archaeologists in China unearthed a collection of complete fossils that had a clear halo of 'dino fuzz' surrounding the skeletal impressions, which they determined must had been a form of primitive feathers, or fur.

The modern expert opinion holds that an entire group of dinosaurs, known as the Theropods, likely bore feathers in some capacity. These would have started as fluffy, primitive barbs but in some species would have evolved into fully established feathered wings that were sometimes used for flying. Perhaps most intriguingly, the beloved velociraptor and the T-rex belong to this group. So these terrifying creatures may have looked much more 'cuddly' than was previously believed.

The colour mystery solved

We may now know that many dinosaurs were adorned with some sort of feathered coat, but what colours were they? If we look to today's avian descendants of the dinosaurs, birds, we see a spectrum of coloured plumage used to perform a bunch of different functions, such as camouflage and attracting a mate. But with limited insight into a dinosaur species' behaviour, we can only make an educated guess as to how these factors could have contributed to their feather colour.

Fortunately, precious fossil evidence lends us concrete proof of the colours worn by dinosaurs, for some colours at least. Using sophisticated microscopes, in well-preserved fossils we can identify impressions of pigment molecules that have been preserved for tens of millions of years.

These pigments have well-defined shapes that are responsible for particular colours, which enable scientists to determine if a dinosaur's feathers bore this hue. We can also compare the structures of these ancient pigments against modern-day birds, allowing us to unlock the secrets of the past by using the present.

Feathered family tree

Theropod feathers evolved to help dinosaurs in a variety of ways, from disguise to flight

Filament

Protofeathers were composed of single hollow filaments. These would later evolve into established feathers in many species.

Tuft

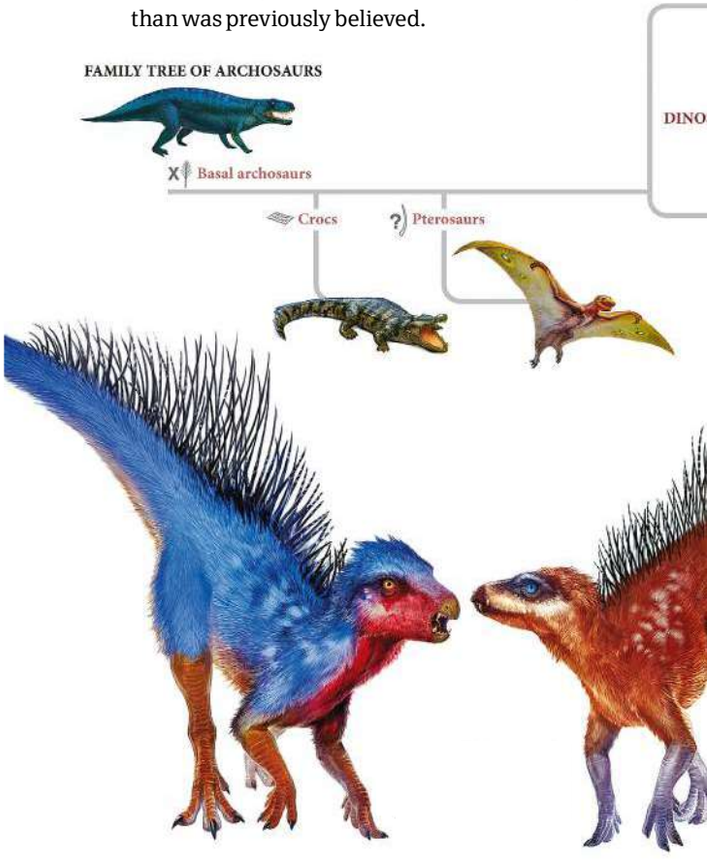
Protofeathers evolved into tufts of several filaments, giving dinosaurs a halo of fluff either in patches or a full coat.

Barbs

Over many generations tufts would have transformed into more rigid and organised structures of barbs connected to a central shaft.

Feather

Eventually, barbs would have been crosslinked by structures known as barbules, producing advanced feathers capable of supporting full flight.



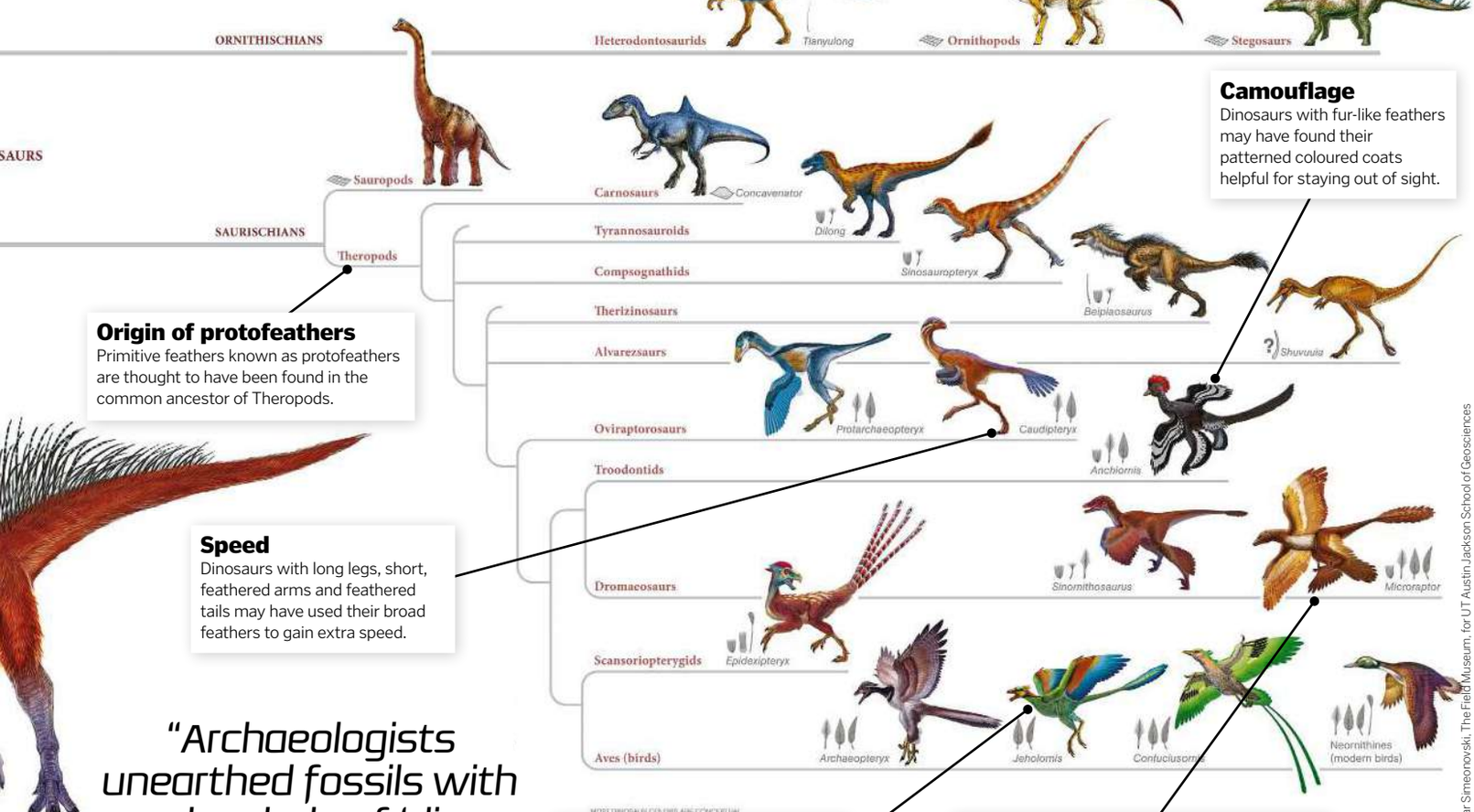
The rainbow dino duck

A duck-sized dinosaur that had the basic shape of a bird and the snout of a raptor likely lit up the forests of the Mesozoic era with its flashy displays. Named as *Caihong juji*, or 'rainbow with the big crest', the recently discovered ancient animal's fossilised remains were found with brilliantly preserved feathers that had retained fragments of pigment sacs known as melanosomes. The shape and orientation of these sacs is most similar to those of iridescent hummingbird feathers, meaning that *Caihong juji* likely had a plumage that vibrantly shone in the colours of the rainbow. We can only speculate as to its purpose, but hummingbirds and peacocks employ vibrant, colourful displays when courting a mate, so it may be that this dinosaur found love the same way.

The *Caihong juji* was discovered to have similar feather pigmentation to colourful hummingbirds

Modern reptiles such as the Komodo dragon inspired us to think that all dinosaurs were scaled, not feathered

Scaled
Many dinosaurs outside of the Theropod branch would have been mostly scaled and sometimes clad in thick armour.



Origin of protofeathers
Primitive feathers known as protofeathers are thought to have been found in the common ancestor of Theropods.

Camouflage
Dinosaurs with fur-like feathers may have found their patterned coloured coats helpful for staying out of sight.

Speed
Dinosaurs with long legs, short, feathered arms and feathered tails may have used their broad feathers to gain extra speed.

"Archaeologists unearthed fossils with a clear halo of 'dino fuzz' surrounding the skeletal impressions"

Flying
Member species with large, feathered arms likely took to the skies and used their long tail to help steer.

Gliding
Some Theropods had feathered legs as well as feathered arms and tails, which meant they probably used the added air resistance for gliding.

JOURNEY THROUGH THE INCREDIBLE WORLD WE LIVE IN

Filled with breathtaking imagery and awe-inspiring facts, explore our amazing planet, from its awesome landscapes and weather wonders to its geological marvels and diverse wildlife.

ON SALE NOW

FUTURE

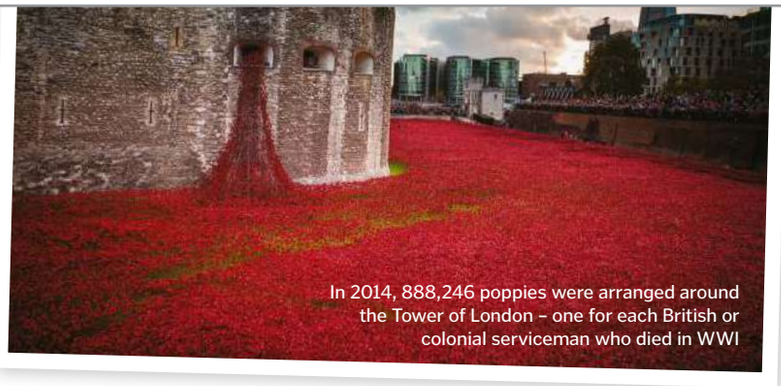
Ordering is easy. Go online at:

www.myfavouritemagazines.co.uk

Or get it from selected supermarkets & newsagents

Why do people wear poppies?

Since 1921 this flower has been used to commemorate the fallen of WWI



In 2014, 888,246 poppies were arranged around the Tower of London – one for each British or colonial serviceman who died in WWI

Contrary to popular belief, the commemorative poppy is a sign of life, not death. The resilient flowers grew out of the barren battlefields of WWI (1914–1918), where little else could survive. They therefore symbolised hope in the aftermath.

The sight of the poppies inspired Canadian soldier Lieutenant Colonel John McCrae to write a poem called *In Flanders Fields*. His words had a powerful effect on the public, in particular American academic Moina Michael. She made it her mission to promote the poppy as a symbol of remembrance by selling silk flowers, which were eventually brought to England.

Artificial poppies were first sold in Britain in 1921, when the Royal British Legion ordered 9 million of them to raise money for WWI veterans. They were sold on 11 November – known as Armistice Day, or Remembrance Day – the date on which WWI ended at 11am.

The first Poppy Appeal was a success, and the British Legion soon set up the Poppy Factory, where ex-servicemen were employed to produce the flowers. The factory still exists, but the veterans require a little help from machines. As Moina Michael wrote, "And now the Torch and Poppy Red, we wear in honour of our dead."

Inside the Poppy Factory

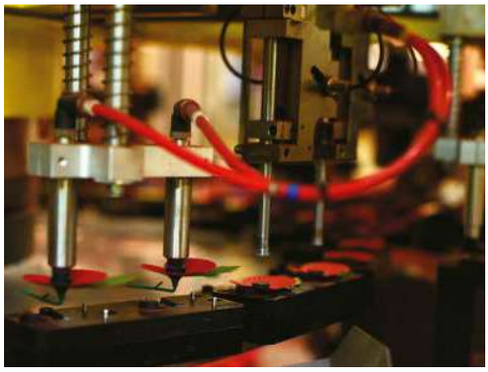
How this symbol of remembrance is made

1 Paper production

Paper passes through the cutting and pressing machines to be shaped into leaves and petals. Manufacturer James Cropper has provided the materials since 1978, when the charity switched from fabric to biodegradable paper.

2 Assembly begins

The stem is placed into a mounting holder and then the leaf and petals are positioned over the top using the tiny hole-punches in the paper. To hold everything together a black button is fixed onto the centre.



3 A helping hand

2 million poppies are assembled by hand, but demand has grown so much that machines are needed to produce over 40 million a year. The buttons are fed into the hopper, a funnel-shaped device that moves them onto the production line.

4 Finishing touches

The finished flowers are packed into boxes and shipped to 88 countries around the world. Poppies and wreaths specially made for the royal family and prime minister are locked away for safe keeping.

In Flanders Fields by John McCrae

In Flanders fields the poppies blow
Between the crosses, row on row,
That mark our place; and in the sky
The larks, still bravely singing, fly
Scarce heard amid the guns below.

We are the Dead. Short days ago
We lived, felt dawn, saw sunset glow,
Loved and were loved, and now we lie,
In Flanders fields.

Take up our quarrel with the foe:
To you from failing hands we throw
The torch; be yours to hold it high.
If ye break faith with us who die
We shall not sleep, though poppies grow
In Flanders fields.

Lieutenant Colonel John McCrae was a Canadian poet, physician and soldier during WWI

BRAIN DUMP

Because enquiring minds need to know...

The James Webb Space Telescope is shown here being tested to ensure it survives the temperature extremes in space

MEET THE EXPERTS

Who's answering your questions this month?

JODIE TYLEY

TOM LEAN

LAURA MEARS

JAMES HORTON

JO STASS

Want answers?

Send your questions to...

How It Works magazine

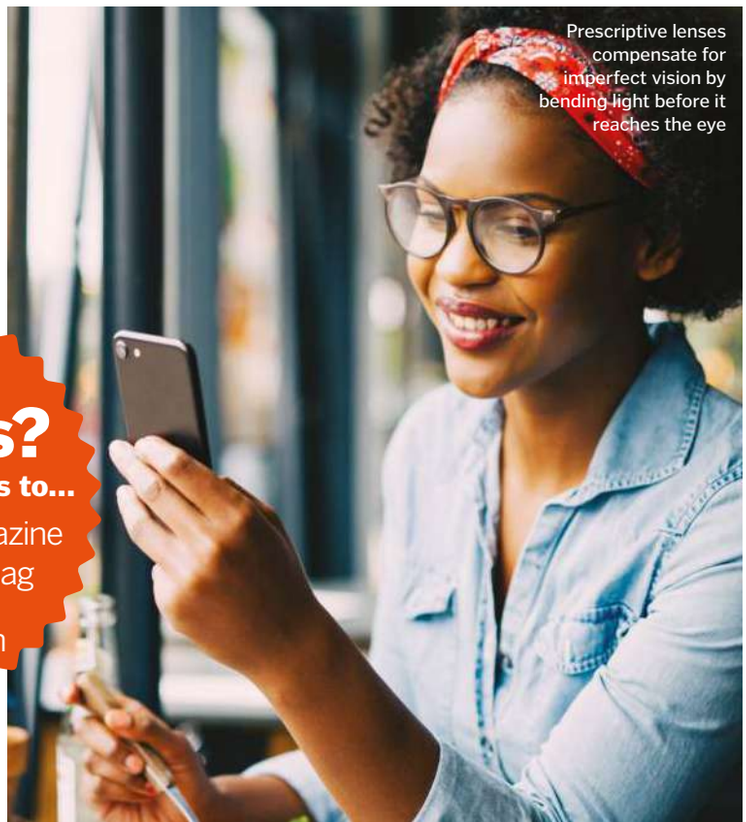
@HowItWorksmag

@howitworks@futurenet.com

Why has the JWST been delayed?

Joey Peters

The James Webb Space Telescope (JWST) was originally supposed to be launched around 2007, but it is now delayed until at least 2021. Some of this is due to simple building mistakes like loose bolts, but mostly it's because the JWST involves lots of new ideas and technology that is far more advanced than the old Hubble Space Telescope. Inventing and testing these new technologies and ideas has taken longer than people first expected, but this isn't surprising because advanced projects like this are often late as they are intended to push science forward by tackling the unknown and solving difficult problems. **TL**



Prescriptive lenses compensate for imperfect vision by bending light before it reaches the eye

How do glasses help to correct your vision?

Darren Carlson

Our eyes provide vision by collecting light through our pupils (the black parts at the centre) and bending the light rays onto the retina at the back of our eye. The cornea and lens are responsible for bending light just right so that it focuses perfectly on the retina. Nearsighted people (who struggle to see things at a distance) focus the light in front of the retina, and longsighted people (who struggle to see things that are close) focus light behind the retina. Glasses with corrective lenses bend light before it reaches our eyes, which helps to ensure that the light ends up focused on our retinas. **JH**

'Heavy water' is used in nuclear reactors to slow down neutrons released during nuclear fission

What is heavy water?

Marisa Pembroke

Hydrogen atoms naturally come in three forms: protium, deuterium and tritium. Protium is the most common form of hydrogen and is composed of one proton and one electron. Deuterium has a neutron alongside the proton in the nucleus, and tritium has two neutrons.

If water has a large amount of deuterium instead of protium, then it has more neutrons than typical water and thereby earns itself a new name: 'heavy water'. If water contains more tritium it becomes 'tritiated water', which is corrosive and radioactive! **JH**

It's impossible to be offside from a goal kick, corner or throw-in

What is the offside rule?

Alvin Marquez

The offside rule states that when a player passes to a teammate who's in the opponent's half, there must be at least two players from the opposing team between the forward player and the goal. Ultimately, it's there to stop players from lingering at the opponent's goal uncontested and gaining an advantage. **JH**

BRAIN DUMP

Laughter makes our hearts beat faster and increases blood pressure

What physiologically happens inside your body when you laugh?

Hideo Nakahara

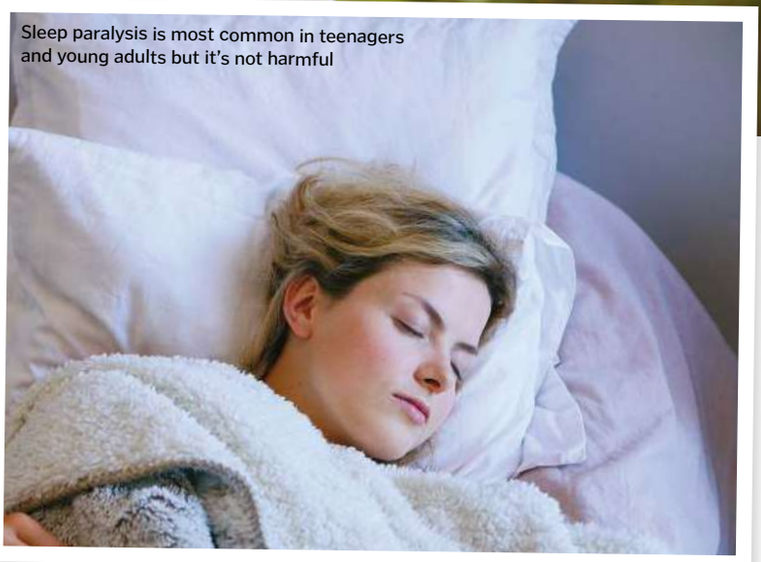
When we laugh our blood pressure goes up, our hearts beat faster, the rhythm of our breathing changes and the levels of chemicals in our brains shift. All of these changes to our physiology add up to many health benefits, including relieving tension and helping with breathing problems. Regular laughter might even help to reduce levels of the stress hormone cortisol, helping to keep the immune system on top form. **LM**

Who was Otzi the Iceman?

April Carter

In 1991, tourists found the mummified 5,300-year-old body of a man in the Alps. Nicknamed 'Otzi the Iceman', he's now kept at the South Tyrol Museum of Archaeology in Italy. Otzi was around 45 years old, about 1.6 metres tall and weighed around 50 kilograms. He wasn't in the best of health, and repairs to his equipment suggest that he'd been on the move for quite some time. He was travelling along a ridge when he died, had just enjoyed a meal of wild goat and grains, and was carrying a fancy-looking copper axe, which suggests that he might have been a man of some status. **LM**

This reconstruction shows what Otzi might have looked like

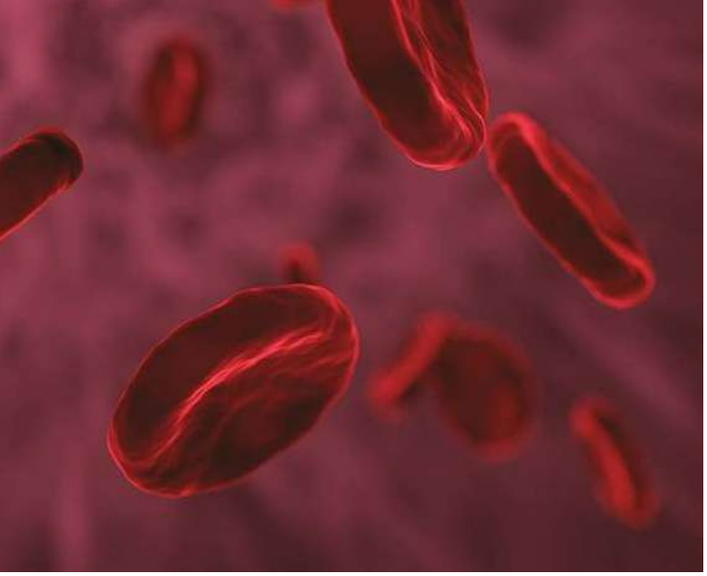


Sleep paralysis is most common in teenagers and young adults but it's not harmful

What is sleep paralysis?

Luther Sullivan

During a normal night's sleep, the brain will enter a state known as REM (Rapid Eye Movement), during which dreams often occur – usually towards the end of a sleep cycle. In order to stop any physical reaction to the dreams taking place the body enters a paralytic state, preventing the muscles from moving. However this state can also occur during wakefulness, leaving the brain conscious but with the body temporarily unable to move. **JT**



Why don't red blood cells have a nucleus?

Petra Novak

■ Red blood cells do have a nucleus when they are created, but these are destroyed as the cells mature. With no nucleus, red blood cells have more space in which to store haemoglobin, the molecule that holds onto oxygen. More haemoglobin means that the cells can carry more oxygen around inside our bodies. **TL**

What's the closest living relative of the dodo?

Ida Griffin

■ The Nicobar pigeon is the dodo's closest living relative. It's a colourful bird found mainly in the Nicobar Islands in Southeast Asia, but sadly its population is declining. **JS**

The game Mouse Trap is based on the idea of a Rube Goldberg machine

What is a Rube Goldberg machine?

Olga Jankovic

■ Named after illustrator Rube Goldberg, who was famous for cartoons of silly gadgets, Rube Goldberg machines are overly complicated contraptions designed to perform simple tasks in ridiculously complex ways. **TL**

Why do microwaves' plates rotate?

Mellie Wilson

■ Microwave ovens heat your food using short radio waves called microwaves that bounce off the walls inside the oven and then travel through your food. As they only hit your food from certain angles, the plate spins to make sure no areas are missed, heating your food evenly. **JS**

Is it cruel for puppies to be separated from their mother?

Lewis Shelton

■ It would be cruel to separate a puppy from its mother during the first eight weeks of its life, as during this time it feeds on her milk to get important nutrients and antibodies and learns appropriate behaviour from her and its littermates. However, once the puppy has been weaned onto solid food, the mother is likely to want to spend less time with it anyway so that it can learn to survive without her. Puppies may feel a little anxious about the separation at first, but with lots of attention from their new owner they will soon be happy without their mother. **JS**

Puppies should not be separated from their mother until they are eight weeks old

BRAIN DUMP

What does space smell like?

Lamia Bitar

■ Astronauts on the ISS, who picked up 'space molecules' during space walks, described near-space to have a 'meaty' and 'metallic' smell. Also, the centre of our galaxy contains lots of ethyl formate, which smells like rum! **JH**

Why does body temperature feel warm to us?

Jess Shoemaker

■ Our optimal core temperature is 37 degrees, but our bodies are constantly generating heat. We need to get rid of the excess and we can't do that if it's the same temperature outside, so we end up feeling warm. **LM**

Squinting allows you to focus more clearly, but glasses work better

Why does squinting help us see things better?

George Benneton

■ When you look at something, light travels through your eye and is detected on the retina at the back. Most of the improvement from squinting is due to it shrinking what you can see and reducing the amount of light from the edges of your vision. This means all the light hitting your retina is coming from the centre of your vision without interference from the edges, so you can focus clearly. **TL**

How is elastane/ spandex made?

Nat Chambers

■ Elastane fibres are made from two types of prepolymer molecule mixed together: flexible macroglycol, which gives the fibre its stretch, and diisocyanate, which provides the rigidity and strength. This solution is forced through the small holes of a metal plate called a spinnerette to turn it into strands of liquid polymer, then heated to create a chemical reaction that turns it into solid strands. These strands can then be twisted together to form the flexible elastane fibre. **JS**

Elastane is easily stretched but also holds its original shape

Want answers?

Send your questions to...

How It Works magazine

@HowItWorksmag

@howitworks@futurenet.com

What causes dimples?

Callum Ward

Scientists aren't completely sure really. Patterns of dimples in families suggest that it might be genetic, but lots of babies lose their dimples as they get older, and some people gain them in later life. Whatever the cause, it seems to affect the shape and size of the cheek muscles, changing the way they sit under the skin. **LM**

The whites of our eyes enable us to communicate better

Why do we show the whites of our eyes?

Mylene Verhoek

The white of the eye, also known as the sclera, is highly visible in humans as there is more of it exposed and it's unpigmented. Theories suggest that this evolution occurred because of the need to communicate with others. Researchers also found that the amount of sclera on show is proportionate to body size and walking height, suggesting that this is an adaptation for extending the field of vision by eyeball movement. It saves us energy because we don't need to turn our heads as much. Nonhuman primates, on the other hand, have dark sclera that conceals their gaze from other individuals and potential predators. **JT**

What was the Pony Express?

Troy Ross

In the mid-19th century the Pony Express was the fastest mail delivery service. Horse riders would race across North America to deliver letters from east to west in ten days. It only ran for 18 months, but the legend lives on. **JT**

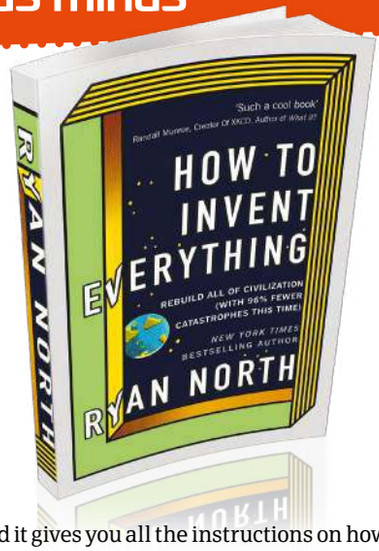
Does an email have a carbon footprint?

Becci Anderson

Sending even a short email adds about four grams of carbon dioxide equivalent into the atmosphere, a study estimates. That's because of the greenhouse gases produced in running the computer, server and routers, and manufacturing the equipment. **JT**

BOOK REVIEWS

The latest releases for curious minds



How to Invent Everything

Stranded in history? This is the book for you

- Author: **Ryan North**
- Publisher: **Virgin Books UK / Riverhead Books US**
- Price: **£16.99 / $27**
- Release date: **Out now**

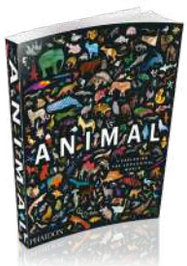
As we looked at the contents of Ryan North's light-hearted trip (literally) through history, we laughed out loud. It's not often that a contents page makes you laugh, but then most history books don't have chapters titled 'Major schools of philosophy summed up in a few quippy sentences about high-fives'. We flicked straight to the page, and to our surprise and joy the chapter quite literally did what the title had promised.

This 'history' book is unlike any you will have ever read. In fact, it reads more like science fiction in some places. The premise is that this is an instruction manual for a time machine that gets stuck in the past. Within ten pages you're told that if it's broken, you won't be able to fix it. Instead it gives you all the instructions on how to accelerate human evolution.

It works brilliantly, especially when coupled with North's (sorry, we mean Chronotix Solutions' copywriter's) relaxed and humorous tone. At one point, when describing how to splint a broken bone, the author says how painful it is, and therefore if you do it to yourself it is extremely badass and you should definitely tell people afterwards.

There are excellent illustrations, an astonishing breadth of topics and enough science to keep most readers entertained. Above all, this book is an exceptionally entertaining read and well worth a look.

★★★★★



Animal: Exploring the Zoological World

- Author: **Various**
- Publisher: **Phaidon**
- Price: **£39.95 / $59.95**
- Release date: **Out now**

PERFECT FOR... NATURE LOVERS

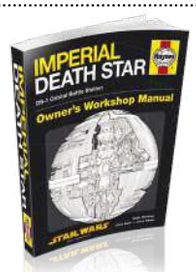
This captivating book explores humanity's fascination with the animal kingdom throughout history. Combining cave art, medieval studies, modern illustrations and more, this is a truly unique title.

The Science of Spice

- Author: **Dr Stuart Farrimond**
- Publisher: **DK**
- Price: **£20 / $25**
- Release date: **Out now (UK) / 6 Nov (US)**

PERFECT FOR... THE FOODIE

Learn all about the science behind the flavours of world's best spices in this beautiful in-depth guide. From the chemistry of flavour compounds to creating the perfect blend, it's ideal for any curious cook.

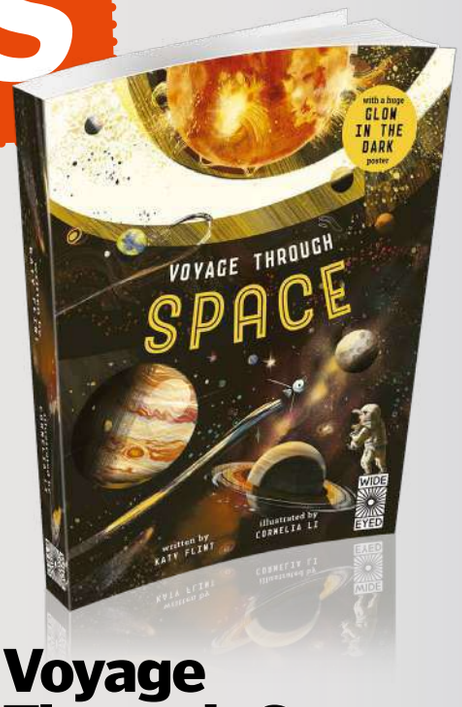


Imperial Death Star Owner's Workshop Manual

- Author: **Ryder Windham, Chris Reiff, Chris Trevas**
- Publisher: **Haynes**
- Price: **£16.99 / $24**
- Release date: **Out now**

PERFECT FOR... SCI-FI FANS

Discover the origins, construction and operations of the infamous planet destroying superweapon from the *Star Wars* universe in this incredibly detailed guide from Haynes.



Voyage Through Space

An illustrated journey through the universe

- Author: **Katy Flint**
- Publisher: **Wide Eyed Editions**
- Price: **£12.99 / $19.99**
- Release date: **Out now**

Space is an exciting topic for youngsters. It's a great unknown, filled with stars, planets and maybe even aliens in their young minds. But if you've got a child that wants to know more about our Solar System, Katy Flint is here to help.

Written to be child-friendly, this edition explores each planet (as well as the Sun, the asteroid belt and Pluto) across a double page. We explore along with a young astronaut and her dog, who are on a mission to understand the celestial bodies in our system. Each spread has a beautifully illustrated image of the planet by Cornelia Li that really helps to bring the information to life.

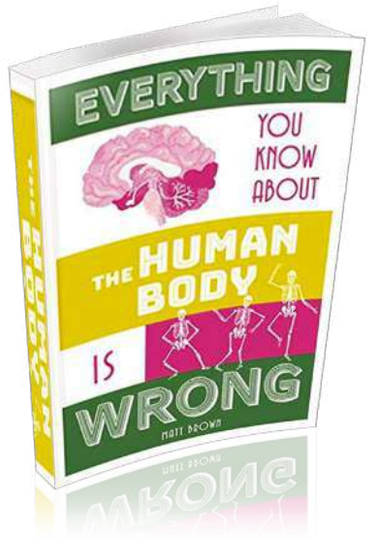
The science here is very basic as the intended audience is young – this is clearly a book designed for parents to read with their children. Some of the facts are likely to spark other conversations about space and the Solar System, which might require further research afterwards, but most children will enjoy the amount of knowledge here, even if they can't necessarily comprehend the thought of the centre of the Sun being 15 million degrees Celsius.

The imagery alone makes this well worth a read. For younger readers wanting to explore space with their parents, this is an excellent first step.

★★★★☆

Everything You Know About the Human Body is Wrong

How your body *actually* works



- Author: **Matt Brown**
- Publisher: **Batsford**
- Price: **£9.99 / $12.95**
- Release date: **Out now**

Think you know your own body? Of course you don't – try naming every single part of it and what it does. You'll lose interest above all else. Fortunately, here's something that will help you learn about yourself and keep you engaged.

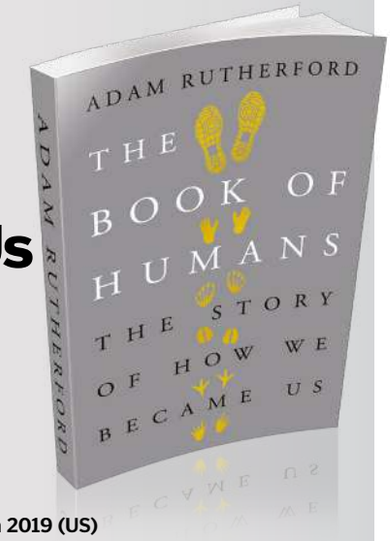
This collection of trivia is both conversational and informative, uncovering the truth behind certain statements you will have heard numerous times before (such as we only use ten per cent of our brains) and whether TV actually is bad for your eyes. The answer to that last question will be especially gratifying for some.

While other books in the series covered such wide-spanning themes as space and science, it's nice that the localised surrounds of our own selves can prove to be just as fruitful a source of wonder.

★★★★☆

The Book of Humans: The Story of How We Became Us

Search for the human inside ourselves



- Author: **Adam Rutherford**
- Publisher: **Weidenfeld & Nicolson**
- Price: **£18.99 / £25.95**
- Release date: **Out now (UK) / 19 March 2019 (US)**

Having discovered more about yourself than you probably cared to find out, why not learn about how we became us? If you liked Yuval Noah Harari's *Sapiens: A Brief History of Humankind*, then this could be the next item on your list.

Although less epic in scope than Harari's work, this is nonetheless an achievement. Adam Rutherford knows how to craft a narrative, and not one that's solely chronological. His story of humankind is interwoven with the story of other living organisms, our story going hand in hand with that of the other species we share this beautiful planet with. Whatever lessons we've learned over the years, we haven't done so alone.

Both as a follow-up to Matt Brown's book and as a companion to Harari's, this represents some even more poignant reading about a subject we could all do with knowing more about: ourselves. Put this one in the stocking.

★★★★☆

Timelines of Everything: From Woolly Mammoths to World Wars

Here's how it happened

- Author: **Various**
- Publisher: **Dorling Kindersley**
- Price: **£20 / $29.99**
- Release date: **Out Now**

It's a widely accepted truth that timelines look great, but not only do they look visually appealing, they're also efficient and really useful. All the history you need about a certain subject matter is right there in front of you, doing the hard work for you.

It turns out that *Timelines of Everything* isn't far off the mark as a title. Covering dense time periods like prehistory and the universe itself, along with themes such as democracy and time, civilisations like the Celts and Vikings, and in-depth lowdowns on events like the eruption of Mount Vesuvius, there are over 100 pieces of subject matter for you to enjoy.

This is not the kind of thing you'd usually see DK do and is a departure from their usual visual style, but they've excelled nonetheless. Yep, shocker, we're recommending you get another DK book. Not our fault they're almost always so darn good.

★★★★★

Robot: Meet the Machines of the Future

The world of the future... today!

- Author: **Various (foreword by Dr Lucy Rogers)**
- Publisher: **Dorling Kindersley**
- Price: **£14.99 / $19.99**
- Release date: **Out now**

DK has long been a master at crafting information-packed compendiums that entice younger readers. As far as subject matter goes, there is little more eye-catching than robots.

Moving beyond what we see in the latest sci-fi thrillers, however, this touches upon the many robots in existence today, as well as showing how they have the potential to enhance our lives in the future. From helpers and kitchen assistants to drones and life-savers, we will be surprised if you have genuinely recognised everything on show here. If you didn't think we'd advanced this far then you're not alone; we didn't either.

While being predominantly aimed at kids, this doesn't talk down to its target audience and as a result is ideal for grown-ups looking to snatch a glimpse at their kids' stocking filler. Plus, it'll all be worth it for the moment you get to the R5 Valkyrie. It looks simply majestic.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

C	Q	D	E	R	E	H	P	S	O	I	B	G	A	R
R	O	L	O	C	I	N	H	C	E	T	D	C	B	E
E	B	P	E	K	O	E	R	B	W	K	I	F	E	M
K	P	H	A	T	R	W	I	L	X	N	E	H	G	E
E	G	O	J	H	N	F	A	S	H	I	O	N	A	M
P	P	M	P	F	E	Q	H	D	K	R	V	J	G	B
O	H	C	S	P	L	A	K	E	J	I	A	O	G	R
C	J	F	K	R	I	C	R	U	M	P	N	Y	A	A
S	E	N	G	I	N	E	Y	I	I	E	T	G	B	N
O	B	L	Z	H	V	F	S	B	N	C	R	I	D	C
R	A	F	E	A	T	H	E	R	S	G	E	T	M	E
C	X	P	K	N	M	W	G	H	I	A	J	K	X	B
I	G	A	S	B	A	O	C	D	G	O	I	Z	F	E
M	U	D	I	J	S	E	O	L	H	X	S	B	Q	A
L	W	E	L	L	S	B	K	N	T	M	F	A	R	H

FIND THE FOLLOWING WORDS...

BAGGAGE
BIAS
BIOSPHERE
ENGINE
EXTREME
FASHION
FEATHERS
HEARING
INSIGHT
MASS
MICROSCOPE
MOON
POPPIES
RAF
REMEMBRANCE
SKIN
TECHNICOLOR
WELLS

Quickfire questions

Q1 What was the intended date for the Gunpowder Plot?
- 5 November 1595
- 5 November 1603
- 5 November 1605
- 5 November 1625

Q2 Which drink was first produced in Nazi Germany due to restrictions on Coca-Cola syrup imports?
- Root beer
- Ginger ale
- Dr Pepper
- Fanta

Q3 Which mountain's peak is furthest from Earth's centre?
- Everest
- Chimborazo
- K2
- Mauna Kea

Q4 How many pairs of ribs do humans have?
- 24
- 6
- 12
- 10

Spot the difference

See if you can find all six changes we've made to the image on the right

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

	6	3	2	9		5		8
8	9	4	3			6	1	
2		7	1	8		4	9	3
	2	5		6	9		8	
7		6	4		1		3	5
4					3		2	6
6	3		9	4			5	7
5		8		1			4	9
	4		5	3	7	8		

VERY DIFFICULT

1					9	7	6	
					6		4	
5	6	3	7		8		2	
	2		9				5	
	9		4		7			6
4							8	3
	1				5	6		
		5						
		6	8	3				

What is it?

Hint:

In the rainforest, not over the rainbow

A .....

© Getty

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 Jack-o'-lanterns

Q2 All of the above

Q3 Da Vinci

Q4 I, V, X, L, C, D, M

What was it?

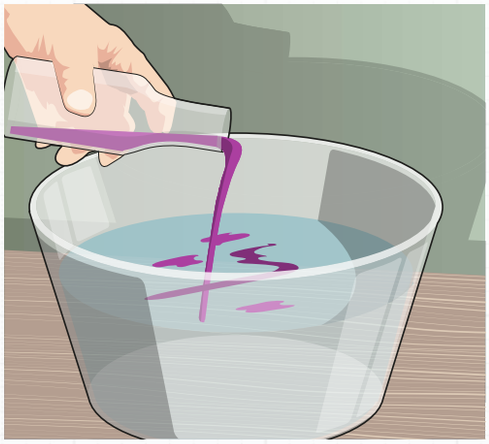
A dog's nose

Get in touch
Send your ideas to...
How It Works magazine
@HowItWorksmag
@howitworks@futurenet.com

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

Make lava in a glass

Create a gloopy, lava-like substance from items you have at home



1 Fill your glass

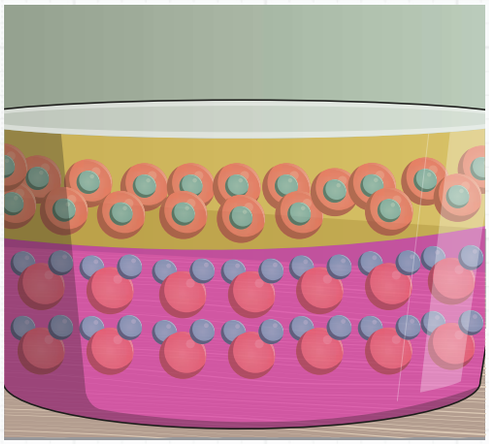
Firstly, find a small glass or a deep glass bowl. Fill it around three-quarters full with water, then add a few drops of food colouring. You can use any colour you want, but red will give it an authentic lava look!

2 Add the oil

Now pour one-quarter of a glass of cooking oil into the water. You'll see that the oil rises to the top of the water, with a clear separation between the two liquids. This is because oil is less dense than water.

3 Try to mix

See if you can get the two liquids to mix by stirring the mixture. You won't have much luck! This is because water molecules are polar – a little like a magnet, they have charges at each end that attract them to each other.

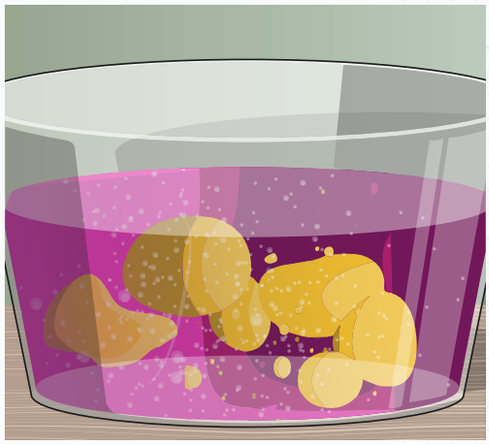


4 Hydrophobic oil

The oil molecules are hydrophobic ('water-fearing') and non-polar. Because their charge is spread evenly they aren't attracted to the water molecules at all. Combined with its lower density, this makes the oil rise to the top.

5 Add some salt

But not for long! Sprinkle a teaspoon of salt into the glass. You should notice some blobs of coloured oil sinking down into the glass then rising up again. The effect is a little like that of a lava lamp.



6 Try more options

Try adding more salt to the glass. Is there a point at which the experiment stops working? You can also try using a differently shaped glass, a different type of oil or different food colouring – how does this affect your results?

HOW IT WORKS...

When you pour in the salt each granule sinks through the oil and into the bottom of the water, taking a blob of oil with it. The salt then dissolves in the water and the oil can rise back to the top. Would you get the same affect with sugar?

Had a go? Let us know! If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

NEXT ISSUE
MAKE A FESTIVE WREATH

WIN A MEGA PRIZE BUNDLE WORTH OVER £1,000!

We're giving one lucky reader a chance to win this amazing selection of gadgets, toys and books – perfect as an early Christmas present for yourself or to give as gifts to friends and family!

To be in with your chance to win, head online to **howitworksdaily.com** to answer this simple question...

WHAT DOES RAF STAND FOR?

A) **ROYAL AIR FORCE** B) **REALLY AWESOME FORCE** C) **ROYAL ARMED FORCES**

Enter online at howitworksdaily.com and one lucky reader will win!

Competition opens on 01/11/2018 and runs until 00:00 on 29/11/2018. Terms and conditions apply. See **futurepic.com/competition-rules** for details.

INBOX
Speak your mind...

Get in touch
If you have any questions or comments for us, send them to...

How It Works magazine @HowItWorksmag howitworks@futurenet.com

The higher up you go, the colder it gets, but planes fly above the clouds responsible for making rain and snow

Letter of the Month

Altitude and snow

Dear **HIW**,

Your latest magazines have been fascinating, but in one of them it made me think of a strange question. In the French Alps people often say it snows a lot because of altitude.

If this is true then how come in England, a country more northerly than France, when you are in an aeroplane and it is raining, you can only see rain instead of snow?

Many thanks,

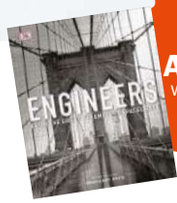
Pascal Ahearne, aged 12

Hi, Pascal. You have made a great observation. The answer is a bit complicated, but it basically comes down to how high above the ground you can find rain-making clouds and how high you have to be for altitude to affect the temperature.

As your plane takes to the sky, you might pass through rain and then some clouds, but after a few minutes you'll notice you're above the fluffy, dense clouds. It's these fluffy clouds that create rain and snow. Once you're at altitude you have passed them, and you're now surrounded by a different type of cloud that doesn't precipitate, so you only experience rain or snow during take-off or landing.

These low-level clouds are usually not high up enough that they are affected that much by altitude, so if it is raining on the ground it will also be raining in these low-level clouds (or at least forming ice in such small snowflakes that they melt the instant that they touch your plane window).

In England it rains a lot, and we have these low-level clouds at relatively low altitude because the country is close to sea level (not at high altitude). However, when you're on the mountains you're at a much higher altitude, and so are the rainmaking clouds, which means they are able to make a lot of snow. We hope that answers your question Pascal, and thanks for writing to us.



WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
ENGINEERS BY ADAM HART-DAVIS
Write to us this month for your chance to win a copy of *Engineers*, a book about the extraordinary tales of the greatest engineers that have ever lived and how they have left their mark on the world.

Lab-grown meat tastes almost exactly the same as traditional meat but contains less fat

Petri dish burgers

Dear **HIW**,

I have a question about lab-grown meat. Is it true that we will be eating burgers that have been grown in petri dishes one day? And if it is true, how does it work and when will it be available in supermarkets?

Thank you for your answer,

Naresh

Hi, Naresh – great question. It is true that some companies have started growing meat in petri dishes. The first person to do this was Professor Mark Post of Maastricht University. He made the first burger patty that was grown in a laboratory. It was done by taking stem cells from a cow, which were grown into strips of muscle. Since then, lots of other start-up companies have developed similar products, including lab-grown chicken and duck. As for when it will be available in supermarkets, the company JUST, Inc. have said their products will be available before the end of 2018.

The invention of plastic

Hello,

When was plastic made and how? Thank you!

Aidan

Naturally plastic materials – like rubber and gum – have been in use for a while, but the plastic we use today is synthetic. This was first invented in 1907 by Leo Baekeland and was called Bakelite. He made plastic using high temperatures and pressure to create a polymer that was mixed with fillers to produce a moldable plastic.

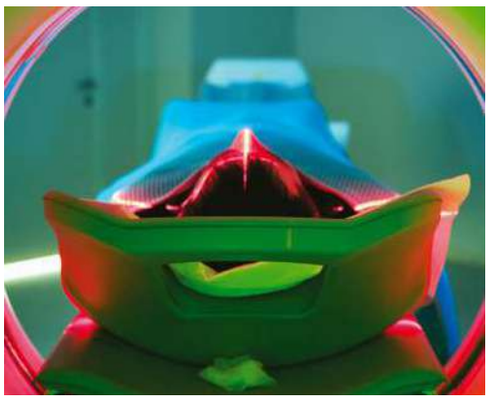
Cancer rates

Hello,

I read today that 1 in 2 people will be diagnosed with cancer at some point in their life. Do scientists know why cancer rates are getting so high? Thank you **How It Works**.

Natalia

Hi, and thanks for your question. The biggest reason that cancer is so prevalent today is because we are living much longer. Age is the biggest risk factor for most cancers, and over 60 per cent of cancer diagnoses are in people who are over the age of 65. We can't stop ageing, but we can reduce our risk of cancer in other ways, like avoiding smoking and drinking, staying active and eating healthy foods.



Plant cuttings

Hi to the **How It Works** team,

I have been trying to plant and grow cuttings of plants and it made me wonder, how do plant cuttings take root and grow?

Thanks,

Beth :)

Hi, Beth. All of the 'growing' of a plant happens in clusters of stem cells within the roots and shoots called meristems, which can grow into any type of plant tissue. So if you take a cutting from the stem of the plant the cells can grow into root cells.

The stem cells in the cutting will start forming roots and growing when it is placed in soil

What's happening on... social media?

This month, we asked you...

If humans were to colonise Mars, what would you name the first Martian city and why?

"Athena. Ares and Athena were the Greek gods of war. Athena was seen as intelligent and structured. Perfect for the first city on an untamed planet."
@TheOnlyAlisonL

"Iris - after my favourite flower because I would want to try and grow one there!"
@h_igoe

"Mac .... After the film Mac and me"
@Jeanettel1979

"Phoenix after the Phoenix lander spacecraft that landed on Mars"
@no_reason21

"New Earth because it would remind us where we came from. Kind of like New England or York"
@pixiee1

"VITAL as to colonise Mars it would be both necessary and world-shattering! A new city would be full of energy, of great importance, and indispensable to the continuance of life there... Vital sums this all up I think"
@bexstarrh

NEXT ISSUE...

Issue 119 on sale **29 NOV 2018**

Available in print from all good newsagents and **myfavouritemagazines.co.uk**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 42 (UK) and 75 (US).

HOW IT WORKS

Future PLC Richmond House, 33 Richmond Hill, Bournemouth, Dorset, BH2 6EZ

Editorial
Editor **Jackie Snowden**
Senior Art Editor **Duncan Crook**
Research Editor **Baljeet Panesar**
Production Editor **Charlie Ginger**
Staff Writer **Charlotte Evans**
Staff Writer **Scott Dutfield**
Group Editor in Chief **James Hoare**

Contributors
Adrian Mann, Ed Crooks, James Horton, Joanna Stass, Jodie Tyley, Jonathan O'Callaghan, Laura Mears, Lee Cavendish, Nicholas Forder, Stephen Ashby, Steve Wright, The Art Agency, Tim Williamson, Tom Lean, Victoria Williams

Cover images
Alamy, Getty Images, NASA

Photography
Alamy, Getty Images, NASA, Science Photo Library, Shutterstock, Thinkstock, Wikimedia

Advertising
Media packs are available on request
Commercial Director **Clare Dove**
clare.dove@futurenet.com
Group Advertising Director **Mark Wright**
mark.wright@futurenet.com
Advertising Manager **Toni Cole**
toni.cole@futurenet.com
01225 687368
Media Sales Executive **Jagdeep Maan**
jagdeep.maan@futurenet.com
01225 687353

International
How It Works is available for licensing. Contact the International department to discuss partnership opportunities
International Licensing Director **Matt Ellis**
matt.ellis@futurenet.com

Subscriptions
Email enquiries **contact@myfavouritemagazines.co.uk**
UK orderline & enquiries **0344 848 2852**
Overseas order line and enquiries **+44 (0)344 848 2852**
Online orders & enquiries **www.myfavouritemagazines.co.uk**
Head of subscriptions **Sharon Todd**

Circulation
Head of Newstrade **Tim Mathers**

Production
Head of Production **Mark Constance**
Production Project Manager **Clare Scott**
Advertising Production Manager **Joanne Crosby**
Digital Editions Controller **Jason Hudson**
Production Manager **Vivienne Calvert**

Management
Managing Director **Aaron Asadi**
Commercial Finance Director **Dan Jotcham**
Editorial Director **Paul Newman**
Head of Art & Design **Greg Whittaker**

Printed by Wyndeham Peterborough, Storey's Bar Road, Peterborough, Cambridgeshire, PE1 5YS

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9001

ISSN 2041-7322

We are committed to only using magazine paper which is derived from responsibly managed, certified forestry and chlorine-free manufacture. The paper in this magazine was sourced and produced from sustainable managed forests, conforming to strict environmental and socioeconomic standards. The manufacturing paper mill holds full FSC (Forest Stewardship Council) certification and accreditation

FAST FACTS

Amazing trivia to blow your mind

THERE ARE OVER 1,000 KNOWN SPECIES OF TARDIGRADE, AND THEY HAVE EXISTED FOR AT LEAST 500 MILLION YEARS

IT'S ESTIMATED THAT THE MILKY WAY HAS THE MASS OF

960 BILLION SUNS

PROLONGED EXPOSURE TO SOUNDS OVER

85 DECIBELS

– EQUIVALENT TO HEAVY CITY TRAFFIC – CAN CAUSE HEARING LOSS

OVER 80°C

THE TEMPERATURE HYPERTHERMOPHILES CAN SURVIVE AT

OVER 30 MILLION

REMEMBRANCE POPPIES ARE MADE AT THE POPPY FACTORY IN SURREY, UK, EACH YEAR

THE AVERAGE ADULT HAS AROUND

2m²

OF SKIN

"NEVER IN THE FIELD OF HUMAN CONFLICT WAS SO MUCH OWED BY SO MANY TO SO FEW" – WINSTON CHURCHILL, 20 AUGUST 1940, PAYING TRIBUTE TO THE RAF DURING THE BATTLE OF BRITAIN

390m

THE DEEPEST HAND-DUG WELL IN THE WORLD IS IN WOODINGDEAN, UK

The world's first colour film was shot in 1902 by British photographer Edward Turner

THE CREW OF THE FIRST BIOSPHERE 2 MISSION LIVED IN THE ISOLATED ECOSYSTEM FOR

2 YEARS

THE DEEPEST-LIVING ORGANISM KNOWN TO SCIENCE IS THE 'DEVIL WORM' (*HALICEPHALOBUS MEPHISTO*), WHICH LIVES 3.6KM UNDERGROUND

THE INSIGHT LANDER WILL ENTER THE MARS' ATMOSPHERE AT **5.9km/s**

IN EUROPE,

95%

OF A CAR BY ITS WEIGHT MUST BE RECOVERED, REUSED OR RECYCLED WHEN IT'S SCRAPPED

Digital Camera PHOTOGRAPHER OF THE YEAR 2019

NOW FREE TO ENTER!

Sponsored by

mpb.com

www.photocrowd.com/dcpoty

Digital Camera YOUNG PHOTOGRAPHER OF THE YEAR 2019

Sponsored by

AFFINITY PHOTO

POWERBALL® GYROSCOPES

DEVELOP YOUR OWN GRAVITATIONAL FORCES...LIKE TINY SPINNING PLANETS

280 Classic
The Entry One

280 Autostart Classic
The All Round One

Diablo Evo Autostart
The Muscle One

280 Autostart Pro
The Best Selling One

Titan
The Most Powerful One

280 Autostart Fusion
The Amazing One

amazon

Over one thousand
5-star reviews

powerballs.com

A zero gravitational training aid for NASA astronauts, Powerball® develops over 60 times its own weight in gyroscopic resistance and delivers strengthening and rehabilitation for the arms & wrists unlike anything else on *(or off)* this planet.

9021

9000